EXPERT REPORT OF VICTOR J. BIERMAN, JR.

State of Oklahoma, et al., Plaintiffs
v.
Tyson Foods, Inc., et al., Defendants

Case No. 05-CV-0329-GKF-SAJ

United States District Court for the Northern District of Oklahoma

January 23, 2009

Victor J. Bierman, Jr.

Victor J. Bierman, Jr., Ph.D.
Senior Scientist

TABLE OF CONTENTS

Summary of Opinions and Supporting Statements on Expert Report by Dr. Bernard Engel 1
Opinions and Supporting Statements on Expert Report by Dr. Bernard Engel 3
Summary of Opinions and Supporting Statements on Expert Report by Dr. Scott Wells 39
Opinions and Supporting Statements on Expert Report by Dr. Scott Wells 40
Opinions on Expert Report by Dr. Jan Stevenson 47
Opinion on Expert Report by Drs. G. Dennis Cooke and Eugene Welch 50
References 51

Appendix A. Curriculum Vitae for Victor J. Bierman, Jr.
Appendix B. Analysis of GLEAMS Model Input Files
Appendix C. LOADEST Results for Phosphorus Loads to Lake Tenkiller
Appendix D. Errors in GLEAMS Model Input and Output Files
Appendix E. Partial Summary of Miscellaneous Errors and Lack of Documentation

LIST OF TABLES

Table 1. Sample Table A-19 in GLEAMS 3.0 Manual (Knisel and Davis 2000) with Nutrient Parameter File for Broiler Litter Applied on Bermuda Grass 4 Times per Year with Multiple Cuttings of Grass 54
Table 2. Sample Table A-20 in GLEAMS 3.0 Manual (Knisel and Davis 2000) with Plant Nutrient Parameter File, Default Initialization, 2-Year Rotation, Inorganic Fertilizer and Animal Manure 55
Table 3. Sample Table A-21 in GLEAMS 3.0 Manual (Knisel and Davis 2000) with Plant Nutrient Parameter File for Forest, Default Initialization, 7-Year Simulation, No Harvest, No Fertilizer, No Tillage 56

LIST OF FIGURES

Figure 1. Sediment Delivery Ratio as a Function of Watershed Drainage Area (from Mills et al. 1985) 58
Figure 2. Key to Interpretation of Color Infrared Imagery for the Illinois River Watershed ... 59
Figure 3. Examples of Forested Land Classified as Pasture by Dr. Engel in his GLEAMS Model 60
Figure 4. Examples of Urban Land Classified as Pasture by Dr. Engel in his GLEAMS Model 61
Figure 5. Examples of Roads Classified as Pasture by Dr. Engel in his GLEAMS Model 62
Figure 6. Map of Rain Gage Locations 63
Figure 7. Map of Locations for Plaintiffs' Soil Test Phosphorus Measurements 64
Figure 8. Map of Locations of USGS Sampling Stations with Measurements for Daily Average Flow 65
Figure 9. Map of Locations of Sampling Stations for Plaintiffs' Measurements of Total Phosphorus at Edge-of-Field 66
Figure 10. Map of Locations of Sampling Stations for Measurements of Total Phosphorus Concentrations in Streams and Rivers in the IRW 67
Figure 11. Map of Sampling Locations for Plaintiffs' Measurements of Total Solids at Edge-of-Field 68
Figure 12. Map of Locations of Sampling Stations for Measurements of Total Solids in Streams and Rivers in the IRW 69
Figure 13. Dr. Engel's Calibration Results for Daily P Load near Tahlequah (top panel), Baron Fork at Eldon (middle panel) and Caney Creek near Barber (bottom panel) with Lines of 1:1 Correspondence between Predicted and Observed Loads 70
Figure 14. Dr. Engel's Purported Validation Results for Daily P Load near Tahlequah (top panel), Baron Fork at Eldon (middle panel) and Caney Creek near Barber with Lines of 1:1 Correspondence between Predicted and Observed Loads 71
Figure 15. Dr. Engel's Combined Calibration/Purported Validation Results near Tahlequah for his Predicted Daily P Loads (top panel) and Daily P Concentrations that Correspond to these Predicted P Loads (bottom panel) 72
Figure 16. Dr. Engel's Combined Calibration/Purported Validation Results for Baron Fork at Eldon for his Predicted Daily P Loads (top panel) and Daily P Concentrations that Correspond to these Predicted P Loads (bottom panel) 73
Figure 17. Dr. Engel's Combined Calibration/Purported Validation Results for Caney Creek near Barber for his Predicted Daily P Loads (top panel) and Daily P Concentrations that Correspond to these Predicted P Loads (bottom panel) 74
Figure 18. Differences Relative to Correct Observed Loads for Two Different Versions of Observed Total P Loads Calculated by Dr. Engel: One Version in Table 5.3 of Dr. Engel's Expert Report and the other in his Routing Model Spreadsheet ("p_model_10_15.xls") 75
Figure 19. Combined Calibration/Purported Validation Results for Daily P Load near Tahlequah (top panel), Baron Fork at Eldon (middle panel) and Caney Creek near

Barber with Chronologies of Predicted GLEAMS Plus WWTP Loads Reversed from Last Day to First Day for each Watershed 76

Figure 20. Ranges of P Loads from WWTPs (top panel) and Nonpoint Source Runoff from GLEAMS (bottom panel) that Can Still be Calibrated to the Observed P Loads to Lake Tenkiller in Dr. Engel's Expert Report 77

Figure 21. Dr. Engel's Combined Calibration/Purported Validation Results near Tahlequah for his Predicted Daily P Loads (top panel) and Daily S&P 500 Stock Index Values (bottom panel) for 1998-2006 78

Figure 22. Differences Relative to Correct Observed Loads for Total P Loads Calculated by Dr. Engel for Dr. Wells to use in his Model of Lake Tenkiller for each Subwatershed and the IRW 79

Figure 23. Differences Relative to Correct (SRP) Observed Loads for the Soluble Phosphorus (SP) Loads Actually Calculated by Dr. Engel for Dr. Wells to use in his Model of Lake Tenkiller for each Subwatershed and the IRW 80

Figure 24. Comparisons Between Predicted (top) and Observed (bottom) Values for Relative Proportions of the Three Algal Groups in Dr. Wells' Model at Station LK-04 in Lake Tenkiller (Dr. Wells' Produced Materials, Dated January 25, 2008) 81

Figure 25. Comparisons Between Predicted (top) and Observed (bottom) Values for Relative Proportions of the Three Algal Groups in Dr. Wells' Model at Station LK-01 in Lake Tenkiller (Dr. Wells' Produced Materials, Dated January 25, 2008) 82

Figure 26. Comparisons Between Predicted (top) and Observed (bottom) Values for Relative Proportions of the Three Algal Groups in Dr. Wells' Model at Station LK-04 in Lake Tenkiller (Dr. Wells' Produced Materials, Dated May 21, 2008) 83

Figure 27. Comparisons Between Predicted (top) and Observed (bottom) Values for Relative Proportions of the Three Algal Groups in Dr. Wells' Model at Station LK-01 in Lake Tenkiller (Dr. Wells' Produced Materials, Dated May 21, 2008) 84

Figure 28. Comparisons Between Predicted (top) and Observed (bottom) Values for Relative Proportions of the Three Algal Groups in Dr. Wells' Model at Station LK-04 in Lake Tenkiller (Run 200 in Dr. Wells' Expert Report) 85

Figure 29. Comparisons Between Predicted (top) and Observed (bottom) Values for Relative Proportions of the Three Algal Groups in Dr. Wells' Model at Station LK-01 in Lake Tenkiller (Run 200 in Dr. Wells' Expert Report) 86

Figure 30. Comparisons Between Predicted (top) and Observed (bottom) Values for Relative Proportions of the Three Algal Groups in Dr. Wells' Model at Station LK-04 in Lake Tenkiller (Run 400 in Dr. Wells' Second Errata) 87

Figure 31. Comparisons Between Predicted (top) and Observed (bottom) Values for Relative Proportions of the Three Algal Groups in Dr. Wells' Model at Station LK-01 in Lake Tenkiller (Run 400 in Dr. Wells' Second Errata) 88

Figure 32. Map of Locations of Plaintiffs' Sampling Stations in Third-Order Streams for Summer 2006 89

SUMMARY OF OPINIONS AND SUPPORTING STATEMENTS ON EXPERT REPORT BY DR. BERNARD ENGEL

1. **The entire construct put forth by Dr. Engel is fundamentally flawed. His modeling framework is conceptually flawed and not appropriate for the IRW.**
   a. The phosphorus mass balance in Dr. Engel's expert report is an inappropriate construct and is not relevant to the relationship between phosphorus sources and water quality.
   b. The GLEAMS model used by Dr. Engel is an inappropriate tool for predicting watershed-scale nonpoint source phosphorus loads to streams and rivers in the IRW.
   c. The phosphorus routing model developed by Dr. Engel is not a valid representation of the real system of streams and rivers in the IRW, and is an inappropriate tool for predicting delivery of phosphorus loads to Lake Tenkiller.

2. **The methods used by Dr. Engel in applying his modeling framework to the IRW are inconsistent with generally accepted practices in the scientific community, contain numerous and substantial errors, and are not reliable to a reasonable degree of scientific certainty.**
   a. The GLEAMS model developed by Dr. Engel for predicting nonpoint source phosphorus loads to streams and rivers in the IRW misrepresents important basic features of the watershed.
   b. Dr. Engel ignored most of the available data in the IRW when he provided the inputs for rainfall in his GLEAMS model.
   c. Dr. Engel ignored most of the available data in the IRW when he provided the inputs for initial soil phosphorus concentrations in his GLEAMS model.
   d. Dr. Engel ignored most of the numerous individual sources of phosphorus loads in the IRW when he provided the inputs to his GLEAMS model.
   e. Most of the inputs for Dr. Engel's GLEAMS model are default or generic values and are not based on conditions in the IRW.
   f. In contravention to generally accepted practices in the scientific community, Dr. Engel did not compare the predictions for hydrology from his GLEAMS model to any observed data in the State of Arkansas or to most of the observed data in the State of Oklahoma.
   g. In contravention to generally accepted practices in the scientific community, Dr. Engel did not compare the predictions for phosphorus loads to edge-of-field from his GLEAMS model to any observed data in the States of Arkansas or Oklahoma.
   h. In contravention to generally accepted practices in the scientific community, Dr. Engel did not compare the predictions for phosphorus loads from his routing model to any observed data in the State of Arkansas or to most of the observed data in the State of Oklahoma.

i. The calibration approach used by Dr. Engel for his models was circular and fundamentally flawed, and his purported validation is inconsistent with U.S. EPA guidance on environmental models.

j. Dr. Engel did not follow his own published guidance on procedures for standard application of hydrologic/water quality models.

k. The observed phosphorus loads to Lake Tenkiller calculated by Dr. Engel for his calibration and purported validation of his models are incorrect.

l. The simulations of future conditions conducted by Dr. Engel with his models fail to account for any changes in phosphorus loads due to changes hydrology, meteorology, population, land uses, urbanization or livestock in the IRW over the next 50 to 100 years.

m. The body of work put forth by Dr. Engel contains large numbers of errors, internal inconsistencies, incorrect unit conversions, incorrect labeling, missing files and missing or incomplete documentation.

3. The modeling results put forth by Dr. Engel in his expert report are not accurate or reliable to a reasonable degree of scientific certainty.

a. The routing model developed by Dr. Engel can be calibrated using a wide range of different watershed loadings, including random values; consequently, his calibration does nothing to corroborate his GLEAMS model outputs or his WWTP loads.

b. The opinion by Dr. Engel that poultry litter land application in the IRW is a substantial contributor to phosphorus loads to Lake Tenkiller is based on model results and methods that are conceptually flawed, incorrect and not reliable.

4. The flawed and unreliable results put forth by Dr. Engel, and relied upon by other Plaintiffs' experts, create a domino effect and render the opinions of these other experts flawed and unreliable to the extent that they relied upon his results.

a. The total phosphorus loads to Lake Tenkiller calculated by Dr. Engel for Dr. Wells to use for calibrating his model of Lake Tenkiller are incorrect; consequently, this calls into question Dr. Wells' entire model calibration.

b. The loads of dissolved ortho phosphate to Lake Tenkiller calculated by Dr. Engel for Dr. Wells to use for calibrating his model of Lake Tenkiller are based on the wrong form of phosphorus, which further calls into question Dr. Wells' entire model calibration.

c. The results for simulations of future phosphorus loads to Lake Tenkiller that Dr. Engel provided to Dr. Wells are flawed and unreliable; consequently, all of Dr. Wells' results that link future phosphorus loads to future conditions in the lake are also flawed and unreliable.

d. The results for simulations of future phosphorus loads that Dr. Engel provided to Dr. Stevenson are flawed and unreliable; consequently, all of Dr. Stevenson's results that link future phosphorus concentrations to future conditions in streams and rivers in the IRW are also flawed and unreliable.

OPINIONS AND SUPPORTING STATEMENTS ON EXPERT REPORT BY DR. BERNARD ENGEL

The U.S. Environmental Protection Agency (2008) has issued official guidance on the development, evaluation and application of environmental models. Model evaluation provides information to determine when a model, despite its uncertainties, can be appropriately used to inform an environmental decision. It addresses the appropriateness of a model for a given application, the soundness of the underlying science, the quality and quantity of available data, and the degree to which model results correspond to observations.

Model evaluation includes model corroboration, and sensitivity and uncertainty analyses. This EPA guidance defines model corroboration as quantitative and qualitative methods for evaluating the degree to which a model corresponds to reality. In practical terms, it is the process of "confronting models with data." In some disciplines, this process has been referred to as validation. EPA prefers the term "corroboration" because it implies a claim of usefulness and not truth. Calibration is part of the corroboration process and involves adjusting model parameters until model predictions give the best fit to observed data. Sensitivity and uncertainty analyses investigate how model outputs are affected by changes in selected model inputs.

My expert report begins by addressing the soundness of the underlying science in the models developed by Dr. Engel and the appropriateness of these models for the IRW and the opinions he puts forth. Next it addresses the quality and quantity of the available data, and how these data were used by Dr. Engel to apply his models. Finally it addresses the degree to which the results of Dr. Engel's models correspond to reality. Throughout my report I set forth my opinions on Dr. Engel's methods, results and claims.

1. The entire construct put forth by Dr. Engel is fundamentally flawed. His modeling framework is conceptually flawed and not appropriate for the IRW.

<u>Supporting Statement 1a:</u> The phosphorus mass balance in Dr. Engel's expert report is an inappropriate construct and is not relevant to the relationship between phosphorus sources and water quality.

The phosphorus mass balance in Appendix B of Dr. Engel's expert report is an inappropriate construct that is irrelevant to water quality impacts in IRW streams and rivers, and in Lake Tenkiller. Conceptually, Dr. Engel encased the entire IRW, including all of the air, land and water compartments, in a "bubble" and considered only the phosphorus movements into and out of this "bubble." These phosphorus movements are irrelevant to water quality impacts in the IRW. The only phosphorus movements that are relevant are those that occur inside this "bubble" from land to water or from atmosphere to water.

The mass balance conducted by Dr. Engel completely ignores movement (or delivery) of phosphorus loads from any land-based sources within the IRW to streams and rivers or to Lake

Tenkiller. His analysis does not tell us how much phosphorus reaches the water or how much reaches the lake, and it does not account for WWTP discharges or septic system releases.

On Page 32 of his expert report, Dr. Engel states that poultry production within the IRW is currently responsible for more than 76 percent of the net annual phosphorus additions to the IRW. This claim is based on Dr. Engel's phosphorus mass balance and is a completely misleading representation of the relative contribution of poultry litter phosphorus to water quality impacts in the IRW.

Dr. Engel's mass balance does not consider a "starting point" for phosphorus in the IRW because it includes only sources and sinks of phosphorus, not reservoirs of phosphorus already present. Table 11 in Appendix B of Dr. Engel's expert report indicates that phosphorus additions to the IRW from poultry were 4,642 tons in 2002. From materials produced by Dr. Engel, the total phosphorus mass in the IRW soil in his GLEAMS model is 6,370,998 tons. This reservoir represents the sum of phosphorus mass for actual conditions (1997-2006) in all soil horizons (layers) in his GLEAMS model. The bottom depths of these soil horizons range from 15.24 to 83.93 inches, depending on location.

Consequently, the annual phosphorus addition to the IRW from poultry litter represents less than 0.07 percent of the total phosphorus mass already present in the soil of the IRW, as represented in Dr. Engel's GLEAMS model. This phosphorus mass reservoir of 6,370,998 tons is not accounted for in the phosphorus mass balance that Dr. Engel conducted.

<u>Supporting Statement 1b:</u> The GLEAMS model used by Dr. Engel is an inappropriate tool for predicting watershed-scale nonpoint source phosphorus loads to streams and rivers in the IRW.

GLEAMS (Groundwater Loading Effects of Agricultural Management Systems) was developed to simulate edge-of-field and bottom-of-root zone loadings of water, sediment, pesticides and plant nutrients from agricultural fields. GLEAMS is a field-scale model and operates at daily time scales. Dr. Engel inappropriately used GLEAMS to predict watershed-scale nonpoint source phosphorus loads from the land to streams and rivers for the entire IRW. In addition, he used GLEAMS for the IRW despite its limitations and uncertainties for predicting phosphorus loads that he identified in his own previous work, as discussed below.

In a U.S. Environmental Protection Agency (EPA) report entitled, "TMDL Model Evaluation and Research Needs," Shoemaker et al. (2005) describe GLEAMS as a continuous simulation, field-scale model that assumes that a field has homogenous land use, soils and precipitation. They characterize GLEAMS as an edge-of-field model that has a low level of support for watersheds and no support for receiving waters.

Shoemaker et al. (2005) specifically state three limitations for use of the GLEAMS model:

- Limited to an agricultural field of very small size
- Not suited for bigger watersheds
- Not suited for urban land uses.

Dr. Engel applied the GLEAMS model to the IRW in contravention to all three of these limitations. The IRW is not an agricultural field of a very small size, it has an area of approximately 1,000,000 acres, and it contains many urban land use areas.

In Dr. Engel's GLEAMS model, the combination of land use areas, soil types, rain gage areas and loading zones forms a hydrologic response unit (HRU). The IRW is divided into HRUs and GLEAMS is applied to each HRU. Dr. Engel intersected land use and soil data in a geographical information system (GIS) to identify HRUs. GIS elevation and watershed boundary data are used to subdivide HRUs to place them within individual subwatersheds.

The total area of the IRW is approximately 1,000,000 acres (4,046 km^2) and approximately half of this area is represented as pasture land in Dr. Engel's GLEAMS model. In turn, the individual pasture land use areas in Dr. Engel's GLEAMS model range in size from 206 acres (0.834 km^2) in HRU 13 in the Baron Fork subwatershed to 99,148 acres (401 km^2) in HRU 14 in the Illinois River subwatershed. These areas are much too large to accurately represent local conditions that influence nonpoint source runoff of phosphorus to edges of individual fields. For example, Figure 1 (adapted from Vanoni 1975) shows that sediment delivery ratio within a 99,148 acre (401 km^2) drainage area can range from 8 to 34 percent as the spatial scale increases from an individual field to the whole drainage area. Sediment delivery is important because phosphorus binds tightly to soil (sediment) particles. Consequently, this large an area cannot represent the wide range in local conditions that influence nonpoint source runoff of phosphorus to edges of individual fields.

The land use areas in the IRW to which Dr. Engel applied his GLEAMS model are too large to accurately represent nonpoint source runoff from local sources. His large areas do not accurately represent the hydrology, soils and topography of the fields from which these loads actually originate.

An important practical consequence of this misapplication of GLEAMS is that phosphorus loads from nonpoint source runoff from every parcel of land in the IRW have equal delivery to streams and rivers in the IRW. That is, a pound of phosphorus eroded from the middle of a 99,148 acre pasture land has the same probability of delivery to a stream or river as a pound of phosphorus eroded from near the edge of this pasture. This does not reflect real-world conditions.

Another limitation of GLEAMS for this application is that it has no capabilities for representing phosphorus loads from wastewater treatment plants (WWTPs), an important source of phosphorus in the IRW. Phosphorus loads from WWTPs must be determined independently and added to the nonpoint source runoff loads computed by GLEAMS for each of the three subwatersheds, the Illinois River, Baron Fork and Caney Creek.

Still another limitation is that GLEAMS is an agricultural model and was not designed to represent urban land. This is important because urban land has impervious areas (i.e., roads and pavement) and GLEAMS does not have the capability to represent impervious land areas.

Finally, Dr. Engel himself has identified important limitations and uncertainties in the GLEAMS model. He was a co-author on a paper entitled, "Evaluation of Nutrient Management Plans Using an Integrated Modeling Approach," that was published in Applied Engineering in Agriculture, Volume 23, No. 6, Pages 747-755, 2007. This paper was authored by M.A. Thomas, B.A. Engel, M. Arabi, T. Zhai, R. Farnsworth and J.R. Frankenberger. The study described in this paper involved application of GLEAMS to individual subwatersheds and counties in Indiana to estimate nutrient loads to surface waters.

On Page 751 of this paper it is stated that, *"Estimated annual P loadings were higher than expected based on knowledge of observed P loadings throughout Indiana," and that " ... studies have shown that GLEAMS often poorly represents sediment bound and leached phosphorus (Gerwig et al. 2001)."* Despite these limitations and uncertainties in GLEAMS that he demonstrated in his own work, Dr. Engel still chose to use GLEAMS to predict nonpoint source phosphorus loads to streams and rivers in the IRW.

In summary, GLEAMS is an inappropriate tool for predicting watershed-scale nonpoint source phosphorus loads to streams and rivers in the IRW, and its limitations and uncertainties for these loads have been documented in Dr. Engel's own previously-published work. GLEAMS is simply the wrong modeling tool for accurately representing phosphorus loads to streams and rivers in a watershed of this size, and that contains many urban land use areas.

Supporting Statement 1c: The phosphorus routing model developed by Dr. Engel is not a valid representation of the real system of streams and rivers in the IRW and is an inappropriate tool for predicting delivery of phosphorus loads to Lake Tenkiller.

The phosphorus routing model developed by Dr. Engel does not represent where phosphorus loads come from in the IRW, or where or how they go through the stream and river network, but only where they end up, that is, at the outlets of the Illinois River, Baron Fork and Caney Creek subwatersheds. Not only does Dr. Engel's routing model fail to explicitly represent any physical features or processes in the streams and rivers in the IRW, it does not actually "route" anything from one location to another. It simply takes the nonpoint source phosphorus loads computed by GLEAMS, plus phosphorus loads from WWTPs, and re-distributes them in time. The reason why Dr. Engel developed his routing model in the first place is that his GLEAMS model cannot deliver its own phosphorus loads to Lake Tenkiller.

Shoemaker et al. (2005) characterize GLEAMS as an edge-of-field model that has a low level of support for watersheds and no support for receiving waters. GLEAMS does not have the capability for linking together the separate hydrology outputs and phosphorus loads computed for each of the individual land areas representing different soil types, land use areas, loading zones and rain gage areas in the IRW. A separate routing model must be used to deliver edge-of-field phosphorus loads computed by GLEAMS, plus WWTP loads, through the IRW stream and river network to Lake Tenkiller.

The routing model developed by Dr. Engel does not represent in-stream processes that are considered important in the scientific community.

SERA-17 is an organization of research scientists, policy makers, extension personnel and educators. The mission of this organization is to develop and promote innovative solutions to minimize phosphorus losses from agriculture by supporting, among other things, recommendations for phosphorus management and research.

On Page 4 of SERA-17 (2005), a publication by the Phosphorus Management and Policy Workgroup, it is stated that, *" ... in-stream processes (including biological uptake,* *mineralization, adsorption, desorption, and sedimentation) alter nutrient forms, transport, and eventual impact on larger receiving waters."* The routing model developed by Dr. Engel does not explicitly represent any of these in-stream processes, nor does it explicitly represent streambank erosion or sediment resuspension in any of the streams or rivers in the IRW.

Dr. Engel applied his routing model to each of the three subwatersheds (Illinois, Baron Fork and Caney Creek) in the IRW. Within each of these three subwatersheds, his routing model does not represent individual streams or rivers, or any individual segments thereof, and treats all of the water in each subwatershed as being contained in a single, well-mixed box. Consequently, his routing model assumes that a pound of phosphorus delivered to any stream or river location in the IRW has the same probability of delivery to Lake Tenkiller. That is, a pound of phosphorus delivered to a stream or river location 100 stream miles upstream of the lake has the same probability of delivery to the lake as a pound delivered to a stream or river 1 mile upstream.

In summary, the routing model is a flawed construct developed by Dr. Engel to account for the fact that his GLEAMS model cannot deliver its own phosphorus loads to Lake Tenkiller. His routing model "sees" only the total phosphorus load coming from the watershed and the total phosphorus load delivered to Lake Tenkiller. It does not "see" anything in between, nor does it "see" any individual sources coming from the watershed or even where these sources actually enter the stream and river network. Not only does it not represent any physical features or processes in the streams and rivers in the IRW, it contains no information on the relative contributions of different phosphorus sources from the IRW.

2. The methods used by Dr. Engel in applying his modeling framework to the IRW are inconsistent with generally accepted practices in the scientific community, contain numerous and substantial errors, and are not reliable to a reasonable degree of scientific certainty.

<u>Supporting Statement 2a:</u> The GLEAMS model developed by Dr. Engel for predicting nonpoint source phosphorus loads to streams and rivers in the IRW misrepresents important basic features of the watershed.

When a model is applied to a real world system, it must be set up to accurately represent the basic physical features of the system. The GLEAMS model developed by Dr. Engel to predict nonpoint source phosphorus loads to streams and rivers in the IRW misrepresents important features of the pastures, forests, crop lands, and urban lands in the watershed. These misrepresentations mean that his model cannot accurately predict phosphorus loads from the watershed, nor can it accurately predict the amount of phosphorus loads that come from different land uses. The reason is that different land uses contribute different phosphorus loads per acre and Dr. Engel's GLEAMS model cannot predict either the correct phosphorus loads or the correct phosphorus sources using the wrong land uses.

For example, GLEAMS is an agricultural field-scale model that was not designed to represent urban land use. Dr. Engel applied GLEAMS to all urban lands in the IRW and represented them as agricultural fields for alfalfa-hay. Furthermore, his GLEAMS nutrient input files for these urban lands do not include any inputs from commercial fertilizer for lawns or gardens, or domestic animal wastes from dogs and cats.

Dr. Engel also made numerous errors in which he classified forest lands, urban lands and roads as pasture lands in his GIS data files. For example, Figure 2 shows color infrared imagery corresponding to the 2001 NLCD (National Land Cover Dataset) data used by Dr. Engel for Zone 3 and includes a key to urban, forest and pasture land uses. Figure 3 shows examples of two locations for which Dr. Engel classified forested land in the imagery as pasture land in his GIS files. Figure 4 shows examples of three locations for which Dr. Engel classified urban/commercial land in the imagery as pasture land in his GIS files. Finally, Figure 5 shows examples of two locations for which Dr. Engel classified roads in the imagery as pasture land in his GIS files.

Again, these misrepresentations are important because different land uses will contribute different phosphorus loads per acre and Dr. Engel's GLEAMS model cannot predict either the correct phosphorus loads or the correct phosphorus sources with the land uses represented incorrectly.

There are also substantial inconsistencies between the land use areas in Dr. Engel's GIS data files and those in the hydrology input files he actually used for his GLEAMS model. For example, the GLEAMS hydrology input files for Baron Fork contain 30,531 fewer acres of forest, 2,550 fewer acres of pasture, and 215 fewer acres of urban land when compared to the areas in his GIS data files. Overall, there are 33,296 fewer acres represented in the GLEAMS model for the Baron Fork subwatershed than the total number of acres in the GIS data files from which these drainage areas in the hydrology input files were derived. These discrepancies would favor the Plaintiffs' claims because the GLEAMS model for Baron Fork represents 69 percent pasture land while the GIS data files represent only 59 percent pasture land. This would overstate the relative contribution of pasture land in the Baron Fork subwatershed.

There is also an inconsistency in the total crop area for the IRW between Dr. Engel's expert report (Appendix B, Page 8, Table 1) and the hydrology input files he actually used for his GLEAMS model. The total drainage area for the crop land use in Dr. Engel's expert report is 1,476 acres; however, it is only 145 acres in the hydrology input files to the GLEAMS model. Again, this discrepancy would favor the Plaintiffs' claims because the GLEAMS model would overstate the relative contribution of other land use types in the model.

The errors made by Dr. Engel in representing land uses in the IRW are more than just labeling errors. When the wrong labels are used in a watershed model, then the model not only predicts the wrong loads but it predicts loads from the wrong sources.

<u>Supporting Statement 2b:</u> Dr. Engel ignored most of the available data in the IRW when he provided the inputs for rainfall in his GLEAMS model.

Nonpoint source phosphorus loads to streams and rivers in the IRW are driven by the intensity, frequency, duration and spatial distribution of rainfall. A watershed model cannot get the loads right unless it gets the rainfall right. Watershed models do not predict rainfall, so rainfall must be provided as model input.

On Page 95, Shoemaker et al. (2005) state, *"Ultimately, input of time varying and spatially detailed meteorological information can support more accurate calibration and application of watershed models, particularly in the prediction of hydrology. Hydrology is particularly sensitive to variations in the spatial distribution of precipitation and temperature."*

Dr. Engel applied his GLEAMS model to conditions for 1997-2006. His calibration period was 1998-2002 and his purported validation period was 2003-2006. There are 10 rain gages located within the IRW (Figure 6). These gages represent a total of 749 station-months of rainfall data during 1997-2006, including 461 station-months in Arkansas and 288 station-months in Oklahoma. Dr. Engel ignored the available rainfall data for 548 of these station-months (73 percent) and used the data for only 201 station-months (27 percent) to provide rainfall inputs for his GLEAMS model.

Not only did Dr. Engel ignore 73 percent of the available rainfall data, but the data he did use were not representative of the entire IRW. He used data from only one station (Odell 2N, ID 035354) to represent rainfall inputs for 46 percent of the total IRW watershed area. He used data from four stations (Odell 2N, ID 035354; Stilwell 5 NNW, ID 348506; Tahlequah, ID 348677; and Kansas 2NE, ID 344672) to represent the remaining 54 percent of the IRW watershed area; however, he used data from Kansas 2NE only two percent of the time and data from Tahlequah only 9 percent of the time. Consequently, most of the rainfall inputs in Dr. Engel's GLEAMS model for the entire IRW for 1997-2006 were based on data from only two rainfall stations, Odell 2N and Stilwell 5 NNW.

In summary, a watershed model cannot get the phosphorus loads right unless it gets the rainfall right. Two rainfall gages are not sufficient to get the rainfall right for a 1,000,000 acre watershed because there is too much variation in local conditions across such a large area. In the real world, rainfall is never the same for all pastures in the IRW at the same time.

<u>Supporting Statement 2c:</u> Dr. Engel ignored most of the available data in the IRW when he provided the inputs for initial soil phosphorus concentrations in his GLEAMS model.

Soil phosphorus concentrations are another important input to watershed models because they represent the amount of phosphorus already present in a watershed before phosphorus loads from additional sources are applied, and they also provide a starting point for the models. Specification of initial phosphorus pools is a key step in the site-specific application of the GLEAMS model used by Dr. Engel for the IRW.

On Page 139 of the GLEAMS Manual (Knisel and Davis 2000), in the section on "Initialization of Nitrogen and Phosphorus Pools," it is stated that, *"Initial values of the different conceptualized pools are very site specific and are generally very management dependent. This is especially true for systems with animal waste application, those with intensive management such as high levels of fertility and production, and conservation tillage systems with heavy residues left on the soil surface. Model users are <u>strongly</u> (sic) urged to make every effort to obtain the best estimate possible for these parameters, which may involve soil sampling and analysis."*

To provide the initial values for soil phosphorus for his GLEAMS model for 1997-2006 conditions, Dr. Engel used only county-level data for soil test phosphorus (STP) as summarized in Table 7.1 of his expert report. The STP concentrations in Table 7.1 correspond to the labile phosphorus concentrations (CLAB) in the (surface) soil horizon in Table 6 on Page D-16 of his expert report, through a conversion factor contained in the spreadsheet "Benton and Wash Counties abstracted 2000 to 2007.xls" in his produced materials.

Dr. Engel completely ignored all site-specific measurements for soil phosphorus in samples collected by the Plaintiffs. Between 6/12/2006 and 12/12/2006 the Plaintiffs collected soil phosphorus samples at 60 locations in Oklahoma (Figure 7) and produced 190 measurements of STP. This number does not include blanks, standards, matrix spikes or samples collected but not reported due to field and/or laboratory errors.

Dr. Engel also needed to provide initial values for soil phosphorus for his GLEAMS model for his historical loading scenario (1950-1999). On Page 36 of his expert report Dr. Engel stated that background STP levels in the IRW can be estimated from samples obtained at the Nickel Reserve in the IRW. He cited STP values for forested areas at the Nickel Reserve from 17.4 to 20.6 lb/acre for the top 6 inches of soil and stated that these values would represent a background STP value within the IRW as no phosphorus has been applied to these areas in the form of fertilizer or livestock waste. He cited STP values for pastured areas at the Nickel Reserve from 28 to 37.4 lbs/acre for the top 6 inches of soil and stated that livestock waste and fertilizer have not been applied to these areas for many years, so these STP values would represent likely background levels for pastures that are occasionally grazed by livestock.

In his deposition on January 8-9, 2009, Dr. Engel acknowledged that he did not have a single datum from the State of Arkansas, approximately half of the IRW, to support his assumptions on soil phosphorus levels.

Despite his descriptions of these Nickel Reserve STP values in his expert report, Dr. Engel does not explain whether or how he actually used them in his GLEAMS model. The only explanation he provided on the background STP levels he used in his GLEAMS model is on Page 82 of his expert report. There he stated that for his historical loading scenario (1950-1999), soil phosphorus levels were assumed to be equivalent to current levels (50 ppm = 100 lbs P/acre for a 6 inch soil depth) in Sequoyah County (Table 7.1 and Table 6, Page D-16) which would be considered equivalent to soil phosphorus levels for the entire watershed in 1950.

Finally, Dr. Engel also needed to provide initial values for soil phosphorus in his GLEAMS model for his "No Waste plus Background Soil P" scenario described beginning on Page 76 of his expert report. He did not document the values he used anywhere in his expert report, but from his produced materials he used the same initial values for soil phosphorus in his "No Waste plus Background Soil P" scenario that he used in his historical loading scenario (1950-1999); however, the actual soil phosphorus values for CLAB in his GLEAMS model input files for pasture range between 24.3 and 40 ppm for the different soil layers, and hence do not match the value of CLAB (82 ppm) for Sequoyah County in Table 6 on Page D-16 in his expert report.

Not only did Dr. Engel ignore most of the available data in the IRW when he provided the inputs for soil phosphorus concentrations in his GLEAMS model, including data collected by the Plaintiffs, he failed to document the values he actually used in his GLEAMS model for background soil phosphorus concentrations in the absence of applied poultry litter. This calls into question the results of his historical scenario (1950-1999) and his "No Waste plus Background Soil P" scenario on these grounds alone.

Supporting Statement 2d: Dr. Engel ignored most of the numerous individual sources of phosphorus loads in the IRW when he provided the inputs to his GLEAMS model.

As described on Pages D-18 and D-19 of his expert report, the only phosphorus sources that Dr. Engel stated that he included in his GLEAMS model are poultry litter, manure from other animals (beef cattle, dairy cattle and swine), commercial fertilizer and WWTPs.

Dr. Engel ignored the loads from numerous other individual sources of phosphorus in the IRW when he provided the inputs to his GLEAMS model. This is important because the relative contributions of all phosphorus sources that are included in his models will be overestimated because not all of the real-world phosphorus sources are included.

For example, on Page D-41 of his expert report Dr. Engel stated that a phosphorus mass balance for the IRW will be completed to identify the important phosphorus sources to be considered in his modeling. He goes on to state that point and nonpoint sources of phosphorus of significance (> 2% of P based on mass balance) will be considered. In Table 22 in Appendix B of his expert report, urban runoff and other additions (golf courses, wholesale nurseries and recreational users) are each listed as being less than 2 percent and he does not include these sources in his models. Nowhere in his expert report does Dr. Engel address the collective impact on his results of ignoring individual sources that he assumes to be insignificant.

These are not the only phosphorus sources that Dr. Engel ignored in his models. The Comprehensive Basin Management Plan for the Illinois River Basin in Oklahoma (Haraughty 1999) lists the following phosphorus sources in the IRW in addition to poultry litter:

- Streambank erosion
- Septic systems
- Recreation activities
- Nurseries
- Gravel mining
- Illegal dumping
- Smaller livestock facilities
- Wildlife

Dr. Engel ignored phosphorus loads from all of these sources in his GLEAMS model.

Dr. Engel also ignored phosphorus inputs due to sediment loads from unpaved roads (Watershed Conservation Resources Center 2005), land application of biosolids from WWTPs and WWTP bypasses and overflows (expert report by Dr. Ron L. Jarman), and urban runoff and golf course fertilizer application (Appendix B, Engel expert report). Streambank erosion and sediment loads from unpaved roads are important sources because phosphorus binds tightly to soil and sediment particles.

Supporting Statement 2e: Most of the inputs for Dr. Engel's GLEAMS model are default or generic values and are not based on conditions in the IRW.

Model outputs cannot be accurate and reliable unless the model inputs represent real-world conditions in the system being modeled. In other words, garbage in equals garbage out. Most of the inputs used by Dr. Engel for his GLEAMS model were default or generic values that were not based on data for the IRW, nor were they shown to reasonably represent conditions in the IRW. This calls into question the accuracy and reliability of his model predictions for nonpoint source phosphorus loads to streams and rivers in the IRW.

There are several ways in which a GLEAMS model user can provide plant nutrient input parameters for a particular application. Two examples of such parameters would be CLAB (labile phosphorus concentration in the soil horizon) and RATE (rate of application of animal waste). First, the GLEAMS model itself can provide its own plant nutrient input parameters. For example, if a user provides their own input value for CLAB, GLEAMS can distribute this value into the appropriate computational layers. If soil nutrient data are available for local soils the user should input those values, but if such data are not available, generalized estimates can be generated by GLEAMS itself.

Second, GLEAMS contains a default database for plant nutrient input parameters that represents data compiled from a number of sources and locations. This database is not specific to the IRW. The GLEAMS user can decide whether to use actual data for local soils or the default data base contained in GLEAMS.

Third, as a starting point for a site-specific application, a GLEAMS user could simply decide to use plant nutrient input parameters from the several example tables in the appendices to the GLEAMS Manual (Knisel and Davis 2000). These values could be from the default database in GLEAMS, generalized estimates generated by GLEAMS, or from other sources. Again, these values are not specific to the IRW.

I will use the term "default" to refer to the default values in the GLEAMS database and the generalized estimates generated by the GLEAMS model itself. I will use the term "generic" to refer to values taken directly from one of the example tables in the appendices to the GLEAMS Manual.

The U.S. EPA (2008) guidance on environmental models is clear on the importance of using real-world data for model inputs. On Page 16 it states, "*The most appropriate data ... should always be selected for use in modeling analyses. Whenever possible, all parameters should be directly measured in the system of interest.*" On Page 19 it states, "*Even though a modeling framework (or system of equations) might be technically sound, a particular site-specific application of the modeling framework may still be highly uncertain if the data used to construct the application are limited in quantity or quality. For such an application, the model would not have the necessary scientific credibility or utility to support an environmental decision.*"

On Page 137 of the GLEAMS Manual (Knisel and Davis 2000) in the section on "Nutrient Parameters Description," it states that, "*The plant nutrient component of GLEAMS and the associated parameter values allow the user to make a generalized application with model-initialized parameters or very site-specific detailed user-defined initialization.*" The claims and opinions put forth by Dr. Engel in his expert report on phosphorus loads to Lake Tenkiller, and on which phosphorus loads come from which land uses, are not generalized but are intended to be specific to the IRW. These claims cannot be supported with a generalized application of GLEAMS, but must be supported with site-specific data that reflect real-world conditions in the IRW.

Most of values used by Dr. Engel for his GLEAMS nutrient parameter input files were default or generic values, not values based on any actual data from the IRW. In his expert report, Dr. Engel did not describe any investigations he conducted to determine whether these default or generic values were appropriate for the IRW. This calls into question the accuracy and reliability of his model results.

Summaries of the actual plant nutrient parameter input files that Dr. Engel used for pasture, crop, forest and urban land uses in his GLEAMS model are contained in Appendix B of my expert report. Also included in Appendix B are tables containing line-by-line descriptions of each plant nutrient parameter input file for each of these land uses. Below are concise summaries of my key points for the nutrient parameter inputs used by Dr. Engel in his GLEAMS model.

Pasture is the most important land use category in Dr. Engel's GLEAMS model because he represents almost half of the 1,000,000 acres in the IRW as pasture land and he assumes that poultry litter is applied to every acre of this pasture land. His GLEAMS model inputs for pasture land are based directly on example Table A-19 from the GLEAMS Manual (Table 1). He used 10 default values from GLEAMS and 10 generic values taken directly from Table A-19. Note that blanks in GLEAMS model input files signify that the internal GLEAMS default value is used instead of a value externally specified by the user.

For pasture land, Dr. Engel provided his own values for only seven of the 27 required GLEAMS nutrient parameter inputs (Page D-41 of his expert report):

- AOM: organic matter content in animal waste
- APHOS: total phosphorus content in animal waste
- APORGP: organic phosphorus content in animal waste
- CLAB: labile phosphorus concentration in the soil horizon
- DF: date of fertilizer application
- RATE: application rate for animal waste
- RESDW: crop residue on the ground surface when simulation begins

Apart from CLAB, as discussed above, four of these seven nutrient parameter inputs are described on Page D-18 of Dr. Engel's expert report. These include RATE for total applied litter (223,000 tons/year on a dry weight basis), APHOS (2.08%), APORGP (0.98 organic P/total P) and DF (April 1).

The most important of these GLEAMS nutrient inputs are RATE, APHOS and total applied litter phosphorus (4,642 P tons/year). As described on Pages 19 and 20 in Appendix B of Dr. Engel's expert report and summarized in two spreadsheets (Smith00003221_New_Calculations.xls and Engel00000186_Poultry_Comp_forBernie.xls) produced by the Plaintiffs, the only data from the IRW Dr. Engel used to develop the GLEAMS input values for these parameters were the numbers of birds in each IRW county. All of the other data required to develop input values for these parameters (average manure generation rates in lb/finished bird, average moisture contents, average percent total phosphorus on a dry weight basis, and average bird weights at market) were taken from Nutrient Management Plans (NMPs) for a different watershed than the IRW. Ms. Megan Smith, who conducted the phosphorus mass balance study in Appendix B of Dr. Engel's expert report, under Dr. Engel's direction, admitted in her September 10, 2008, deposition that she does not know if the values reported in these NMPs are calculated numbers or production numbers based on actual data, and that she never investigated this.

Not only were most of the data used to develop these important parameters taken from a watershed other than the IRW, but Dr. Engel ignored phosphorus measurements for litter samples (APHOS) collected by the Plaintiffs from 20 poultry houses in the IRW, as well as samples collected from poultry litter fallen from trucks (Olsen Expert Report, Page 2-3). Dr. Engel derived his value for APHOS by simply dividing total applied litter phosphorus (4,642 P tons/year, Appendix B, Engel expert report) by his value for total applied litter (223,000 tons/year on a dry weight basis) for the IRW.

The rates of poultry litter application (RATE) assumed by Dr. Engel in his GLEAMS model do not reflect actual practices in the IRW. Dr. Engel divided all of the pasture land in the IRW into four zones and assumed that poultry litter in his GLEAMS model was applied uniformly to each acre within each of these four zones. In his deposition he stated that the rates of application he assumed in his model were not the rates per acre actually applied in the IRW. This is important because half of the 1,000,000 acres in the IRW in Dr. Engel's GLEAMS model is represented as pasture land and he applies poultry litter to all pasture land in his model.

Dr. Engel also assumed that all of the poultry litter in his GLEAMS model is applied on a single day each year (NF = 1) for all pasture land in the entire IRW and that this date is April 1 (DF = April 1). This does not reflect actual practices in the IRW, nor is it consistent with Dr. Engel's own expert report. As shown in Figure 4.1 of Dr. Engel's report, poultry litter is applied in the IRW during each month from January to December of each year.

This means that in Dr. Engel's GLEAMS model the total amount of poultry litter applied for the entire year is applied on a single day in a single "heap" regardless of whether it is raining or dry. This does not reflect actual practices in the IRW.

Dr. Engel determined APORGP by using APHOS and assuming that the ratio of organic and total phosphorus taken from the GLEAMS Manual (Knisel and Davis 2000) was appropriate for the IRW. He did not document how he determined AOM or RESDW in his GLEAMS model.

For crop and forest land use areas, again most of nutrient parameter inputs Dr. Engel used for his GLEAMS model are default or generic values, with the exception of CLAB as described above. His GLEAMS inputs for crop land are based on example Table A-20 from the GLEAMS Manual (Table 2). He used 28 default values and 37 generic values taken directly from Table A-20. His GLEAMS inputs for forest land are based on example Table A-21 from the GLEAMS Manual (Table 3). He used 20 default values and three generic values taken directly from Table A-21.

There are no examples for plant nutrient input files in the GLEAMS Manual for urban land because GLEAMS is an agricultural model. Dr. Engel set his GLEAMS inputs for urban land use with alfalfa-hay as the specified crop type. As described above, this is a misrepresentation because urban land is very different than agricultural land for growing hay. Dr. Engel used 18 default values and four generic values taken directly from Table A-21.

Overall, Dr. Engel used default or generic values for 130 of the 140 (93 percent) plant nutrient input parameters that he needed to run his GLEAMS model for the IRW. These default and generic values are not based on site-specific data for the IRW, nor is there any documentation in Dr. Engel's report of investigations he conducted to determine whether these values were appropriate for the IRW.

In summary, the phosphorus component of Dr. Engel's GLEAMS model is almost entirely a generalized application and is not specific to the IRW. Dr. Engel has not demonstrated that the nutrient inputs to his GLEAMS model represent real-world conditions in the IRW. If his model inputs do not represent real-world conditions, then neither can his model outputs. Consequently, Dr. Engel cannot claim that predictions from his model for phosphorus loads to streams and rivers in the IRW, or his predictions for which phosphorus sources come from which land uses, are accurate and reliable.

Supporting Statement 2f: In contravention to generally accepted practices in the scientific community, Dr. Engel did not compare the predictions for hydrology from his GLEAMS model to any observed data in the State of Arkansas or to most of the observed data in the State of Oklahoma.

To demonstrate that a model corresponds with reality it must be "confronted with data." A thorough model evaluation includes comparison of model predictions with the available site-specific data. If substantial portions of the available site-specific data are "left out" during the model evaluation process, a model cannot be considered accurate and reliable. While it would be appropriate to ignore observed data that fail to meet QA/QC criteria or that are not representative of the true system being modeled, Dr. Engel ignored the vast majority of the data available to him when he calibrated and purported to validate the hydrology component of his GLEAMS model.

This point is emphasized on Page 3 of SERA-17 (2005) where it is stated that, *"In our opinion, watershed-scale predictions of loadings to lakes are not reliable unless extensive, site-specific calibration is used."*

There are 15 USGS stations with measurements for daily average flow in the IRW (Figure 8). Dr. Engel compared the hydrology outputs from his GLEAMS model to observed data for monthly average flow at only three of these stations, Illinois River near Tahlequah, Baron Fork at Eldon, and Caney Creek near Barber. These are the last three stations before Lake Tenkiller and are the outlets for each of these three subwatersheds to the lake.

Dr. Engel ignored all of the observed data that were available at the seven USGS stations in Arkansas. These stations represent 22,273 measurements of daily average flow during 1997-2006. Dr. Engel also ignored observed data that were available at five additional USGS stations in Oklahoma besides the three outlet stations. These stations represent 17,074 measurements of daily average flow during 1997-2006.

Overall, there is a total of 50,030 measurements of daily average flow at the 15 USGS stations in the IRW during 1997-2006, including the three outlet stations on the Illinois River near Tahlequah, Baron Fork at Eldon and Caney Creek near Barber. Dr. Engel ignored 79 percent of these measurements in his calibration and purported validation of the hydrology outputs from his GLEAMS model.

It is important to check a watershed model "along the way," not just at the downstream outlets. Failure to do so undermines the accuracy and reliability of the model for attributing the relative contributions of sources in the watershed. It is not just about how much water gets to the outlets, but also about where it came from and how it got there. If a model is to be used to make claims about phosphorus loads originating from local sources in the watershed, then it must be confronted with data that actually represent these local sources.

U.S. EPA (2008) recommends conducting sensitivity analyses to characterize the most and least important sources of uncertainty in environmental models. Sensitivity analysis investigates how model outputs are affected by changes in selected model inputs. On Page D-41 of his expert report Dr. Engel lists eight soil parameters that he calibrated and purported to validate for the hydrology component of his GLEAMS model. Dr. Engel stated in his deposition that he did not perform any sensitivity analyses with his models for the IRW. Consequently, the impacts of uncertainties in his GLEAMS hydrology parameters on the model results were not established and are unknown.

<u>Supporting Statement 2g:</u> In contravention to generally accepted practices in the scientific community, Dr. Engel did not compare the predictions for phosphorus loads to edge-of-field from his GLEAMS model to any observed data in the States of Arkansas or Oklahoma.

Dr. Engel's GLEAMS model predicts phosphorus loads at edges of streams and rivers in the IRW, and his routing model predicts phosphorus loads delivered to Lake Tenkiller at the last three USGS stations upstream of the lake. These two models are linked in series with the output of the GLEAMS model providing the input for the routing model. Dr. Engel uses these two linked models to predict not only the phosphorus loads to Lake Tenkiller, but the relative contributions of poultry litter to these phosphorus loads.

The U.S. EPA (2008) guidance on environmental models states on Page 12, that *"When employing linked models, the project team should evaluate each component model as well as the full system of integrated models at each stage of the model development and evaluation process."* Dr. Engel presented no results in his expert report for the evaluation of his GLEAMS model, but presented results only for his routing model by comparing it with observed phosphorus loads to Lake Tenkiller.

The phosphorus loads to Lake Tenkiller are a "soup" that represent the sum of all phosphorus sources in the entire IRW and contain no information on the relative contributions of any individual source. For Dr. Engel's models to support claims on the relative contributions of poultry litter, they must be "confronted with data" at the source of these poultry litter contributions, not at the last three stations before the lake where these contributions have become part of the "soup." This means that Dr. Engel's GLEAMS model must be compared with observed data at edge-of-field.

This point is emphasized on Page 3 of SERA-17 (2005) where it is stated that, *"In our opinion, watershed-scale predictions of loadings to lakes are not reliable unless extensive, site-specific* *calibration is used. The same can be said for short-term (daily) predictions at the edge-of-field scale."*

Furthermore, on Page 4 it is stated that, *"Datasets that include both edge-of-field P losses and down-stream watershed P losses are uniquely suited to assess the relationship between P losses at the edge of field and P delivery to sensitive water bodies."*

Dr. Engel completely ignored all measurements for total phosphorus in edge-of-field samples collected by the Plaintiffs during his calibration and purported validation of his GLEAMS model. Between 5/14/2005 and 6/22/2006 the Plaintiffs collected edge-of-field samples at 64 locations in Arkansas and Oklahoma (Figure 9) and produced 146 measurements. Again, this number does not include blanks, standards, matrix spikes or samples collected but not reported due to field and/or laboratory errors.

As stated above, U.S. EPA (2008) recommends conducting sensitivity analyses to characterize the most and least important sources of uncertainty in environmental models. On Page D-41 of his expert report Dr. Engel lists the seven most sensitive parameters for his calibration of the phosphorus component of his GLEAMS model. Dr. Engel stated in his deposition that he did not perform any sensitivity analyses with his models for the IRW. Consequently, the impacts of uncertainties in these GLEAMS phosphorus parameters on the model results were not established and are unknown.

Not only did Dr. Engel fail to conduct sensitivity analyses for these seven parameters, but he did not conduct sensitivity analyses for any of the default or generic nutrient parameter inputs to his GLEAMS model discussed above in Supporting Statement 2e. Performing sensitivity analyses would have been a way for Dr. Engel to demonstrate that the seven parameters he identified were actually the most sensitive parameters for his GLEAMS model application.

Supporting Statement 2h: In contravention to generally accepted practices in the scientific community, Dr. Engel did not compare the predictions for phosphorus loads from his routing model to any observed data in the State of Arkansas or to most of the observed data in the State of Oklahoma.

As discussed above in Supporting Statement 2g, to demonstrate that a model corresponds with reality it must be "confronted with data." A thorough model evaluation includes comparison of model predictions with the available site-specific data. If substantial portions of the available site-specific data are "left out" during the model evaluation process, a model cannot be considered accurate and reliable. Again, while it would be appropriate to ignore observed data that fail to meet QA/QC criteria or that are not representative of the true system being modeled, Dr. Engel ignored the vast majority of the data available to him when he calibrated and purported to validate his phosphorus routing model.

On Page 3 of SERA-17 (2005) it is stated that, *"In our opinion, watershed-scale predictions of loadings to lakes are not reliable unless extensive, site-specific calibration is used."*

Furthermore, on Page 4 it is stated that, *"Datasets that include both edge-of-field P losses and down-stream watershed P losses are uniquely suited to assess the relationship between P losses at the edge of field and P delivery to sensitive water bodies."*

There are 253 sampling stations with measurements for total phosphorus concentration in streams and rivers in the IRW (Figure 10). Numerous samples were collected during base flows and high flows between 1997 and 2006. Samples were collected by the U.S. Geological Survey (USGS), Oklahoma Water Resources Board (OWRB), Oklahoma Conservation Commission (OKCC), Arkansas Department of Environmental Quality (ADEQ), Arkansas Department of Pollution Control and Ecology (ARDPCE) and by the Plaintiffs themselves.

Dr. Engel compared the outputs for phosphorus loads from his routing model to observed data for only three of these stations, Illinois River near Tahlequah, Baron Fork at Eldon, and Caney Creek near Barber. These are the last three stations before Lake Tenkiller and are the outlets for each of these three subwatersheds to the lake.

There are 135 sampling stations in Arkansas with measurements for total phosphorus concentration in streams and rivers in the IRW (Figure 10). These stations represent a total of 1,267 measurements during 1997-2006. One hundred seventeen (117) of these stations were sampled by the Plaintiffs between 5/25/2005 and 9/25/2006, who collected 550 of these 1,267 measurements. Again, blanks, standards, matrix spikes and samples collected but not reported due to field/lab error were not included in these counts. Dr. Engel ignored all 1,267 of these measurements when he calibrated and purported to validate his phosphorus routing model.

There are 115 sampling stations in Oklahoma with measurements for total phosphorus concentration in streams and rivers in the IRW, in addition to the three stations on the Illinois River near Tahlequah, Baron Fork at Eldon and Caney Creek near Barber (Figure 10). These stations represent a total of 1,927 measurements during 1997-2006. Eighty-one (81) of these stations were sampled by the Plaintiffs between 5/25/2005 and 9/25/2006, who collected 434 of these 1,927 measurements. Again, blanks, standards, matrix spikes and samples collected but not reported due to field/lab error were not included in these counts. Dr. Engel ignored all 1,927 of these measurements when he calibrated and purported to validate his P routing model.

Overall, there are 3,757 measurements of total phosphorus concentration at 253 sampling stations in streams and rivers in the IRW during 1997-2006, including the three outlet stations. Dr. Engel ignored 85 percent of these measurements when he calibrated and purported to validate his phosphorus routing model.

As discussed above in Supporting Statement 2f, it is important to check a watershed model "along the way," not just at the downstream outlets. Failure to do so undermines the accuracy and reliability of the model for attributing the relative contributions of sources in the watershed. It is not just about how much phosphorus gets to the outlets, but also where it came from and how it got there. For Dr. Engel's models to support claims on the relative contributions of poultry litter to phosphorus loads to Lake Tenkiller, they must be "confronted with data" at the sources of these contributions and "along the way," not just at the last three stations before the lake.

As discussed above in Supporting Statement 2f, U.S. EPA (2008) recommends conducting sensitivity analyses to characterize the most and least important sources of uncertainty in environmental models. On Page D-22 of his expert report Dr. Engel lists four coefficients (a, b, c and initial P accumulation) for his calibration and purported validation of his phosphorus routing models to each of three subwatersheds in the IRW. Dr. Engel stated in his deposition that he did not perform any sensitivity analyses with his models for the IRW. Consequently, the impacts of uncertainties in these phosphorus routing model coefficients on the model results were not established and are unknown.

Supporting Statement 2i: The calibration approach used by Dr. Engel for his models was circular and fundamentally flawed, and his purported validation is inconsistent with U.S. EPA guidance on environmental models.

Model evaluation provides information to determine when a model, despite its uncertainties, can be appropriately used to inform an environmental decision. It addresses the soundness of the underlying science, the quality and quantity of available data, the degree to which model results correspond to observations, and the appropriateness of a model for a given application. Model evaluation includes qualitative and/or quantitative model corroboration, and sensitivity and uncertainty analyses.

Dr. Engel claims to have calibrated and validated his models. The calibration approach he used was circular and fundamentally flawed. Furthermore, his concept of model validation is not only inconsistent with U.S. EPA (2008) guidance on environmental models, but is also at odds with the position by Dr. Scott Wells, another expert for the Plaintiffs who used the results from Dr. Engel's models for his own model of Lake Tenkiller, as discussed below.

Calibration is the process of adjusting model parameters until the resulting predictions give the best possible fit to the observed data. The calibration approach used by Dr. Engel for his models is flawed for four reasons. First, he attempted to calibrate both his GLEAMS and routing models to phosphorus loads to Lake Tenkiller. This is a fundamental conceptual flaw because these models are linked in series and should be independently calibrated. On Page 12 of the U.S. EPA (2008) guidance it states that, *"When employing linked models, the project team should evaluate each component model as well as the full system of integrated models at each stage of the model development and evaluation process."* For the IRW, Dr. Engel's GLEAMS model should be independently calibrated to edge-of-field phosphorus data and the routing model should be independently calibrated to phosphorus data in streams and rivers in the IRW, and to phosphorus loads delivered to Lake Tenkiller.

Second, Dr. Engel calibrated his GLEAMS model to phosphorus loads that are different than the phosphorus loads it actually predicts. GLEAMS predicts nonpoint source loads at edge-of-field locations throughout the watershed, not phosphorus loads to Lake Tenkiller. These edge-of-field locations are far back upstream. For example, there is a distance of 94 river miles from the USGS gage near Tahlequah to the Plaintiffs' edge-of-field sampling location (EOF-Q3) near Sweetwater Creek. Comparing edge-of-field predictions to phosphorus concentrations 94 miles away tells us nothing about how his GLEAMS model corresponds to reality.

Third, the phosphorus loads that Dr. Engel put into his GLEAMS model were not independent of the phosphorus loads he used to compare with his GLEAMS model predictions. During his calibration, he used observed phosphorus loads to Lake Tenkiller to modify the phosphorus loads he put into his GLEAMS model in the first place. He did this by modifying his original model inputs for RATE (rate of animal manure application) and APHOS (total phosphorus content in animal manure) during his calibration in an attempt to match his GLEAMS predictions to his observed phosphorus loads to Lake Tenkiller. In other words, during his calibration he cha the amount of animal manure that he was putting into his model so he would get the right answer. This approach is circular and conceptually flawed because it is tantamount to knowing the answer to a question in advance and then re-formulating the question to better fit the answer.

Fourth, Dr. Engel's calibration of his GLEAMS model is based on soil phosphorus and poultry litter application rates that are inconsistent with observed values. On Pages D-16, D-18 and D-40 of his expert report, Dr. Engel states that his GLEAMS input values for CLAB (labile phosphorus concentration in the soil horizon), RATE (rate of animal manure application), and APHOS (total phosphorus content in animal manure) are all based on observed data. However, he proceeds to modify all three of these parameters during his GLEAMS calibration. This approach is flawed because if these inputs are based on observed data then they should not be altered during the calibration process. Furthermore, Dr. Engel's final GLEAMS calibration results themselves are flawed because they are derived using soil phosphorus and poultry litter application rates that are different than observed values.

The very concept of model validation put forth by Dr. Engel is inconsistent with U.S. EPA (2008) guidance on environmental models. On Page D-27 of his expert report Dr. Engel states, *"Validation is a subsequent testing of a pre-calibrated model with additional field data, usually under different external conditions, to further examine the model's ability to predict future conditions. Validation improves the reliability of the model and reduces the uncertainty in its predictions."*

On Page 64 of U.S. EPA (2008) it states that, *"In this guidance, corroboration is defined as all quantitative and qualitative methods for evaluating the degree to which a model corresponds to reality. In practical terms, it is the process of "confronting models with data" (Hilborn and Mangel 1997). In some disciplines, this process has been referred to as <u>validation</u> (sic). In general, the term "corroboration" is preferred because it implies a claim of usefulness and not truth."*

Consistent with this U.S. EPA guidance, Dr. Engel's purported "validation" should instead be characterized as attempted corroboration because no claim of truth can be implied.

Furthermore, Dr. Engel did not demonstrate that his purported "validation" was an independent measure of the performance of his models. On Page 28 of U.S. EPA (2008) it states that, *"Robustness is defined in this guidance as the capacity of a model to perform equally well across the full range of environmental conditions for which it was designed. The degree of similarity among data sets available for calibration and corroboration provides insight into the robustness of the model. For example, if the dataset used to calibrate a model is identical or statistically similar to the dataset used to corroborate a model, an independent measure of the model's performance has not been provided. In this case, the exercise has provided no insight into model robustness."*

Dr. Engel applied his GLEAMS and phosphorus routing models to data for 1997-2006. His calibration period was 1998-2002 and his purported validation period was 2003-2006. Dr. Engel conducted no assessment of the statistical differences between his "calibration" and "validation" datasets. Consequently, his purported "validation" has not been shown to be an independent measure of the performance of his models, and he has not demonstrated that his models perform equally well across the full range of environmental conditions for which they were designed.

Finally, the concept of model "validation" put forth by Dr. Engel is at odds with the position by Dr. Scott Wells, another expert for the Plaintiffs who used the results from Dr. Engel's models for his own model of Lake Tenkiller. Dr. Wells presented a paper entitled, "Surface Water Hydrodynamics and Water Quality Models: Use and Misuse" at the 23rd Annual Water Law Conference, San Diego, CA, February 24-25, 2005. On Page 9 of that paper Dr. Wells states, *"If a model is applied to an independent data set and the model matches data well with the original parameter set, then one can say that the model was calibrated well to the 2 time periods under consideration. When the term validation is used, it makes others think that the model is "valid" and does not have serious weaknesses. This though can be an inappropriate label. Hence, discarding the term altogether would eliminate this misconception."*

Again, consistent with U.S. EPA (2008) guidance, and with the position by Dr. Wells, Dr. Engel's purported "validation" is an inappropriate characterization and no claims of validity or lack of serious weaknesses can be implied.

Not only were the models in Dr. Engel's expert report not validated, but the calibration approach used by Dr. Engel was circular and fundamentally flawed. Consequently, the results from his models do not have scientific credibility nor are they useful for supporting environmental decisions.

<u>Supporting Statement 2j:</u> Dr. Engel did not follow his own published guidance on procedures for standard application of hydrologic/water quality models.

Dr. Engel was the senior author on a paper entitled, "A Hydrologic/Water Quality Model Application Protocol," that was published in the Journal of the American Water Resources Association, October 2007, Volume 43, No. 5, Pages 1223-1236. This paper was co-authored by Dan Storm, Mike White, Jeff Arnold and Mazdak Arabi.

On Page 1224 of his paper, Dr. Engel stated that, *"By definition, the scientific method is impartial and the results from the application of the scientific method must be reproducible. Therefore, the modeling protocol and associated documentation must provide enough detail to allow the modeling project to be repeated."*

On Page 1231 of his paper, Dr. Engel stated that, *"For projects supporting regulatory decision-making, the USEPA (2002) suggests the level of detail on model calibration in the Quality Assurance Project Plan should be sufficient to allow another modeler to duplicate the calibration method, if the modeler is given access to the model and to the data being used in the calibration process."*

In an E-mail on August 13, 2008, from David Page to Robert George, the following information was provided in response to a request by the Defendants for a step-by-step procedure for generating GLEAMS model outputs for daily phosphorus loads: *"Calibrated yearly GLEAMS files were manually modified to better match P load timing by modifying labile phosphorus concentrations in the soil horizon."*

A letter on December 8, 2008, from Ms. Claire Xidis to Mr. Robert George, stated that *" ... Dr. Engel has informed us that the parameters used for the routing equations are included in the errata. These were obtained by adjusting the parameters to match the observed data. The* *optimization program (lake.exe) was not used in adjusting values rather the initial values obtained from that process were used and adjusted manually."*

Dr. Engel used an automated calibration approach based on the Shuffled Complex Evolution (SCE) algorithm. On page D-42 of his expert report he stated that this will avoid the potential to bias his model calibration. However, even though his SCE was designed to provide optimal results, Dr. Engel manually adjusted his model calibration parameters after his automated calibration procedure. He did not describe or document either of these two sets of manual modifications, nor did he explain the basis for his approach or the criteria he used to evaluate the results of these modifications.

With the information provided, it is not possible for his modeling operations to be reproduced or for another modeler to duplicate Dr. Engel's calibration method even with access to the model and the data used in the calibration process. Apart from lack of documentation for these particular modeling operations, Dr. Engel's expert report, his errata of September 4, and his produced materials that support these documents contain large numbers of errors, internal inconsistencies, incorrect unit conversions, incorrect labeling, missing files and missing or incomplete documentation. Given these deficiencies in Dr. Engel's body of work, he has not met his own requirement that the modeling protocol and associated documentation be sufficient to allow the modeling results to be reproducible.

Scientific peer review is an essential component of the evaluation process to determine when a model can be appropriately used to inform an environmental decision. Peer review evaluates whether the assumptions, methods and conclusions derived from environmental models are based on sound scientific principles.

On Page 1228 of his paper, Dr. Engel stated that, *"An appropriate model should be selected based on .... (4) various other factors including: ..... (e) previous applications of the model and acceptance in the scientific, regulatory, and stakeholder communities; ....* " Dr. Engel provided no citations to previous applications of his phosphorus routing model in his expert report, nor did he provide any citation, documentation or demonstration of acceptance of this model in the scientific community through peer review.

On Page 1229 of his paper, Dr. Engel stated that, *"The scientific literature contains numerous studies on the impacts that various data sources and data errors can have on model results. For example, Chaubey et al. (1999) explored the assumption of spatial homogeneity of rainfall when parameterizing models and concluded large uncertainty in estimated model parameters can be expected if detailed variations in the input rainfall are not considered."*

On Page 1231, of his paper, Dr. Engel stated that, *"Model calibration is often important in hydrologic modeling studies, as uncertainty in model predictions can be reduced if models are properly calibrated. Factors contributing to difficulties in model calibration include calibration data with limited metadata, data with measurement errors, and spatial variability of rainfall or watershed properties poorly represented by point measurements."*

As pointed out above in Supporting Statement 2b, Dr. Engel ignored 73 percent of the available rainfall data in the IRW when he specified the required rainfall inputs for his GLEAMS model. Furthermore, most of the rainfall inputs to Dr. Engel's GLEAMS model for the entire IRW were based on data from only two of the 10 rainfall stations in the watershed.

A watershed model cannot get the phosphorus loads right unless it gets the rainfall right. Two rainfall gages are not sufficient to get the rainfall right for a 1,000,000 acre watershed because there is too much variation in local conditions across such a large area. In the real world, rainfall is never the same for all pastures in the IRW at the same time.

On Page 1231 of his paper, in reference to hydrologic/water quality models, Dr. Engel stated that, *"The model is typically calibrated first to obtain acceptable performance in the hydrologic components, then for sediment, and finally for nutrients, pesticides, bacteria, or other constituents."*

Sediment is important because it transports phosphorus from overland runoff, streambank erosion and resuspension through the stream and river network of the IRW, and to Lake Tenkiller. Dr. Engel himself acknowledged the importance of sediment phosphorus in his own published work. He was a co-author on a paper entitled, "Evaluation of Nutrient Management Plans Using an Integrated Modeling Approach," that was published in Applied Engineering in Agriculture, Volume 23, No. 6, Pages 747-755, 2007. This paper was authored by M.A. Thomas, B.A. Engel, M. Arabi, T. Zhai, R. Farnsworth and J.R. Frankenberger.

The study described in this paper involved application of GLEAMS to individual subwatersheds and counties in Indiana to estimate nutrient loads to surface waters. On Page 751 it is stated that, " *... sediment P accounted for most of the estimated P loadings in model simulations."*

Not only did Dr. Engel skip the sediment calibration step for both his GLEAMS model and his routing model, he stated in his deposition that sediment was not a significant pathway in movement of phosphorus through the stream and river system to Lake Tenkiller. This is completely at odds with commonly accepted scientific understanding and with published studies on the IRW.

For example Terrio (2006), in his USGS report, "Concentrations, Fluxes, and Yields of Nitrogen, Phosphorus, and Suspended Sediment in the Illinois River Basin, 1996-2000," states on Page 7 that, *"Phosphorus is generally transported to surface-water bodies through overland runoff and in association with sediment particles ... "* and that, *"Many elements and compounds, including some forms of nitrogen and phosphorus, absorb to sediment particles and are transported and deposited with the sediment."* On Page 38 he states that, *"The general correspondence between suspended-sediment flux and stream flow is expected in most watersheds and particularly in those with agricultural areas where sediment is transported through overland runoff, bank erosion, and the re-suspension of benthic sediments during periods of precipitation and increased stream velocity."*

In contravention to his own published protocol, his own acknowledgment of the importance of sediment in GLEAMS predictions for phosphorus loads, and commonly accepted practices in the scientific community, Dr. Engel completely skipped the sediment calibration step for both his GLEAMS model and his routing model, despite the fact that observed data were available to calibrate both models, much of it collected by the Plaintiffs.

Dr. Engel completely ignored all site-specific measurements for total solids (sediment) in edge-of-field samples collected by the Plaintiffs during his calibration and purported validation of his GLEAMS model. Between 5/14/2005 and 6/18/2006 the Plaintiffs collected edge-of-field samples at 52 locations in Arkansas and Oklahoma (Figure 11) and generated 58 measurements. Again, this number does not include blanks, standards, matrix spikes or samples collected but not reported due to field and/or laboratory errors. Dr. Engel ignored all of these 58 measurements when he calibrated and purported to validate his GLEAMS model.

As discussed above in Supporting Statement 2g, Dr. Engel's phosphorus loads to Lake Tenkiller are a "soup" that represent the sum of all phosphorus sources in the entire IRW and contain no information on the relative contributions of any individual source. For Dr. Engel's models to support claims on the relative contributions of poultry litter, they must be "confronted with data" at the source of these poultry litter contributions, not at the outlets of the three subwatersheds to Lake Tenkiller where these contributions have become part of the "soup." This means that Dr. Engel's GLEAMS model must be compared with observed data at edge-of-field.

Not only should Dr. Engel's GLEAMS model be compared with observed data at the sources of the nonpoint source runoff it predicts, it should also be compared with observed data "along the way," not just at the last three stations before Lake Tenkiller.

There are 99 sampling stations in streams and rivers in the IRW (Figure 12) with measurements for total suspended solids concentrations during 1997-2006. Sampling was conducted by USGS, OWRB, OKCC, ADEQ, ARDPEC and the Plaintiffs. These stations represent a total of 2,054 measurements. Forty (40) of these stations in Arkansas and 30 in Oklahoma were sampled by the Plaintiffs between 5/25/2005 and 9/25/2006, who generated 364 of these 2,054 measurements. Again, blanks, standards, matrix spikes and samples collected but not reported due to field/lab error were not included in these counts. Dr. Engel ignored all of these 2,054 measurements when he calibrated and purported to validate his routing model.

As discussed above in Supporting Statement 2f, it is important to check a watershed model "along the way," not just at the downstream outlets. Failure to do so undermines the accuracy and reliability of the model for attributing the relative contributions of sources in the watershed. It is not just about how much phosphorus gets to the outlets, but also where it came from and how it got there. For Dr. Engel's models to support claims on the relative contributions of poultry litter to phosphorus loads to Lake Tenkiller, they must be "confronted with data" at the sources of these contributions and "along the way," not just at the outlets to the lake.

On page 1233 of his paper, in reference to describing the model's performance relative to observed data, Dr. Engel stated that, *"Plotting of predicted results and observed results along with the 1:1 line can be helpful in identifying model bias."*

Dr. Engel leads the reader of his expert report to believe that high values of R^2 (e.g., greater than 0.90) equate to a good fit between model predictions and observed data. Such values do not tell the whole story and, by themselves, do not mean that a model is a good model. Predictions and observations should also be compared in other ways to prove that model results are accurate and reliable.

A 1:1 line is one of these other ways. A 1:1 line shows the line of exact match between predicted and observed values. Dr. Engel did not show lines of 1:1 correspondence for any of his calibration or purported validation results for his predicted phosphorus loads.

Figures 13 and 14 show Dr. Engel's calibration and purported validation results, respectively, from his expert report with lines of 1:1 correspondence that I added. All of Dr. Engel's results for predicted daily phosphorus loads show bias. His calibration results for Baron Fork and Caney Creek, and his purported validation results for Baron Fork, are all highly biased. For example, his purported validation results for Baron Fork (Figure 14, middle panel) show an R^2

value of 0.925 but the fit between his predicted and observed phosphorus loads is biased by 47 percent. For example, on this plot a predicted phosphorus load (vertical axis) of 60,000 kg/day corresponds to an observed phosphorus load (horizontal axis) of approximately 120,000 kg/day. Despite a relatively high value of R^2, Dr. Engel's model predictions in this case are "off" by almost a factor of two.

A more significant demonstration of the bias in Dr. Engel's models pertains to the confounding influence of observed USGS flows in his calibration and purported validation results for predicted phosphorus loads. This bias can be understood by recognizing that phosphorus loads cannot be measured directly but are the product of flow times phosphorus concentration. In this sense the phrase "observed phosphorus loads" is a misnomer. What Dr. Engel calls "observed phosphorus loads" are actually estimated phosphorus loads calculated using observed flow and observed phosphorus concentration.

In the routing model equations on Page D-21 of Dr. Engel's expert report, his predicted phosphorus load is calculated using observed daily average flow at the three USGS gages on the Illinois River near Tahlequah, Baron Fork at Eldon and Caney Creek near Barber. That is, Dr. Engel did not use flows computed by his own models to compute his predicted phosphorus loads but instead used actual observed flows. On Page 24 of his expert report, Dr. Engel stated that he used USGS and OWRB samples analyzed for total phosphorus content along with USGS flow data to compute his observed phosphorus loads at these three gaging stations.

Consequently, none of Dr. Engel's calibration or purported validation plots provides unbiased tests of the correspondence between his predicted and observed phosphorus loads because he used observed USGS flows to compute both of these phosphorus loads. Dr. Engel's approach almost guarantees good fits because observed USGS flows will always show good fits to themselves. The correct way to test Dr. Engel's predicted phosphorus loads against observed data is to remove observed USGS flows from both axes and compare Dr. Engel's predicted phosphorus concentrations to observed phosphorus concentrations.

Figures 15-17 show Dr. Engel's combined calibration and purported validation results for 1998-2006 in terms of both his predicted daily phosphorus loads (top panels) and his predicted daily phosphorus concentrations (bottom panels) for the Illinois River near Tahlequah, Baron Fork at Eldon and Caney Creek near Barber, respectively. For all three subwatersheds, the fits between Dr. Engel's predicted phosphorus concentrations and observed phosphorus concentrations explain less of the variability in the data and are more highly biased than the results in Dr. Engel's expert report. For Tahlequah, R^2 decreased from 0.974 to 0.619 and bias increased from 3 to 28 percent. This is significant because most of the load from the IRW to Lake Tenkiller is delivered through Tahlequah. For Baron Fork, R^2 decreased from 0.781 to 0.717 and bias increased from 22 to 28 percent. For Caney Creek, R^2 decreased from 0.625 to 0.255 and bias increased from 21 to 75 percent.

This means that Dr. Engel has overstated the predictive power of his models for phosphorus loads to Lake Tenkiller for all three subwatersheds in the IRW. Unbiased tests of his model predictions indicate that they do not fit the actual data nearly as well as the results in his expert report. These results call into question the accuracy and reliability of the claims and opinions in Dr. Engel's expert report that rely upon these model results.

Supporting Statement 2k. The observed phosphorus loads to Lake Tenkiller calculated by Dr. Engel for his calibration and purported validation of his models are incorrect.

In Table 5.3 on Page 25 of his expert report Dr. Engel presents results for observed phosphorus loads for the Illinois River near Tahlequah, Baron Fork at Eldon and Caney Creek near Barber for 1997-2006. He used these observed phosphorus loads for calibration and purported validation of his models, as described in Section 10 and Appendix D of his expert report.

Dr. Engel stated on Page 24 that he used USGS and OWRB samples analyzed for total phosphorus and USGS flow data to compute these observed phosphorus loads using the approach by Tortorelli and Pickup (2006) and Pickup et al. (2003). From the files produced by Dr. Engel, this method was Model 8 contained in the public-domain LOADEST program developed by the USGS.

Nearly every total phosphorus measurement reported by OWRB was either incorrectly entered in the LOADEST setup files used by Dr. Engel to compute his observed phosphorus loads, or was missing entirely from these setup files. Specifically, during 1998-2006, OWRB reported total phosphorus samples on 225 unique dates for the Illinois River near Tahlequah, Baron Fork and Caney Creek combined. Dr. Engel made data entry errors on the OWRB results for 157 of these sample dates for Tahlequah and Baron Fork. For 68 other sample dates for Caney Creek the data are missing in Dr. Engel's LOADEST set up files. In 2006, there were seven dates for Tahlequah and six dates for Baron Fork on which OWRB reported total phosphorus samples, but none of these samples were used by Dr. Engel in his LOADEST setup files.

Furthermore, there are internal inconsistencies in the observed phosphorus loads used by Dr. Engel. The observed phosphorus loads in Table 5.3 of Dr. Engel's expert report and those in his routing model spreadsheet ("p_model_10_15.xls") should be identical but they are different. This is significant because this spreadsheet contains the observed phosphorus loads that Dr. Engel used in his calibration and purported validation of his routing model for phosphorus loads to Lake Tenkiller.

Finally, the observed phosphorus loads in Table 5.3 and in Dr. Engel's routing model spreadsheet are both incorrect. I calculated the observed total phosphorus loads that Dr. Engel should have calculated, given the correct primary data for total phosphorus concentrations and my understanding of the method he used. Specifically, I used Model 8 in the LOADEST program and, following Tortorelli and Pickup (2006) and Pickup et al. (2003), I used the adjusted maximum likelihood estimation (AMLE) method because some of the total phosphorus concentrations were below reported detection limits. I make no claim that these loads are the best estimates of the actual total phosphorus loads, but only that these are the observed phosphorus loads that Dr. Engel should have calculated given his description of his methods and the materials he produced.

Figure 18 shows the differences, relative to the correct observed phosphorus loads, for the observed phosphorus loads in Table 5.3 of Dr. Engel's expert report and those in his routing model spreadsheet. Results are shown for the sums of annual total phosphorus loads for the Illinois River near Tahlequah, Baron Fork and Caney Creek gaging stations. The observed total phosphorus loads in Table 5.3 of Dr. Engel's expert report range from 77 to 115 percent of the correct values, and those in his routing model spreadsheet range from 59 to 124 percent of the correct values.

Appendix C contains detailed results for the Illinois River near Tahlequah, Baron Fork at Eldon, Caney Creek near Barber, and for all three subwatersheds combined.

Supporting Statement 21: The simulations of future conditions conducted by Dr. Engel with his models fail to account for any changes in phosphorus loads due to changes in hydrology, meteorology, population, land uses, urbanization or livestock in the IRW over the next 50 to 100 years.

Dr. Engel used his models to conduct the following simulations of future conditions:

- Continued waste application (100 years)
- Waste application cessation or "no litter" (100 years)
- Waste application cessation plus buffer scenarios or two "no litter buffer scenarios" (100 years)
- Waste for growth (50 years)

Dr. Engel assumed that the hydrologic and meteorological data from 1997 to 2006 would represent conditions for the next 50 to 100 years on repeating 10-year cycles. He did not use the available long-term historical records to project long-term future conditions, nor did he attempt to account for expected changes in hydrologic and meteorological conditions due to global climate change.

Dr. Engel assumed that population, land use, urbanization and livestock in the IRW would remain at their current levels for the next 50 to 100 years, even though the IRW is experiencing rapid growth and development. For example, on Page 2-4 of his expert report, Dr. Wayne Grip quantified the change in newly developed residential and commercial land areas in the eastern portion of the Illinois River basin, which includes portions of the towns of Rogers, Springdale and Fayetteville, Arkansas, from the late 1970s to the present time. He found that from 1976/1982 to 2006, development increased by 39.3 percent within this area and that new residential and commercial development constituted most of the increase in developed land.

In addition, the following information on trends in human population and livestock appears in Appendix B of Dr. Engel's own expert report:

- Table 2: Human population in the IRW increased from 83,874 people in 1950 to 280,383 people in 2000 (~3.3X increase);
- Table 4: Swine population in the IRW increased from 79,556 pigs in 1949 to 208,243 pigs in 2002 (~2.6X increase);
- Table 4: Dairy cattle population in the IRW decreased from 29,478 dairy cows in 1949 to 10,280 dairy cows in 2002 (~2.8X decrease); and,
- Table 4: Beef cattle and heifers (that calved) population in the IRW increased from 10,379 in 1949 to 101,367 in 2002 (~9.7X increase).

In the face of voluminous data that the IRW is on a path of increasing growth, Dr. Engel did not account for any changes in population, urbanization or livestock in his simulations of future conditions in the next 50-100 years. These changes are important because they will all influence future phosphorus loads in the IRW.

Supporting Statement 2m: The body of work put forth by Dr. Engel contains large numbers of errors, internal inconsistencies, incorrect unit conversions, incorrect labeling, missing files and missing or incomplete documentation.

Dr. Engel was the senior author on a paper entitled, "A Hydrologic/Water Quality Model Application Protocol," that was published in the Journal of the American Water Resources Association, October 2007, Volume 43, No. 5, Pages 1223-1236. This paper was co-authored by Dan Storm, Mike White, Jeff Arnold and Mazdak Arabi.

On Page 1226 of his paper, in a sub-section on "Graded Approach to QA (Quality Assurance) Project Plans," Dr. Engel stated that, *"The intended use of the model is a determining factor because it is an indication of the potential consequences or impacts that might occur because of the QC (Quality Control) problems. For example, higher standards might be set for projects that involve potentially large consequences, such as Congressional testimony, development of new laws and regulations, or the support of litigation."*

Dr. Engel's expert report, his errata of September 4, and his produced materials that support these documents contain large numbers of errors, internal inconsistencies, incorrect unit conversions, incorrect labeling, missing files and missing or incomplete documentation. These results do not meet the normal standards for hydrologic/water quality modeling projects, much less the higher standards suggested by Dr. Engel for projects to support litigation. The deficiencies in QA and QC that I have discovered are too numerous to itemize in detail and I make no claim to have discovered all of them. However, to illustrate the nature and scope of these deficiencies, a partial itemized list is contained in Appendix E.

Based on my experience as a former U.S. EPA National Expert in Environmental Exposure Assessment, and my 35 years of professional experience in the field of environmental modeling, the body of work put forth by Dr. Engel would not pass a federal government agency peer review or a peer review by the scientific community. His body of work does not meet the normal standards for scientific credibility or utility for the support of environmental decisions, much less the higher standards set by Dr. Engel himself for the support of litigation.

Even if Dr. Engel fixes all of these deficiencies and follows SERA-17 guidance, U.S. EPA recommendations on environmental models, and his own protocol for application of hydrologic/water quality models, his entire modeling framework remains conceptually flawed and inappropriate for the IRW.

3. The modeling results put forth by Dr. Engel in his expert report are not accurate or reliable to a reasonable degree of scientific certainty.

Supporting Statement 3a: The routing model developed by Dr. Engel can be calibrated using a wide range of different watershed loadings, including random values; consequently, his calibration does nothing to corroborate his GLEAMS model outputs or his WWTP loads.

The models developed by Dr. Engel are insensitive to changes in the timing of his phosphorus loads to streams and rivers in the IRW and to wide ranges in the magnitudes of his phosphorus loads from nonpoint source runoff and WWTPs. It can even be shown that predictions from Dr. Engel's phosphorus routing model can still be calibrated to his observed phosphorus loads to Lake Tenkiller for random inputs. In practical terms, Dr. Engel's models cannot tell the difference between actual phosphorus loads to streams and rivers in the IRW and phosphorus loads that are simply made up.

I conducted a series of analyses with the phosphorus routing model described on Page D-21 of Dr. Engel's expert report. I conducted these analyses using Dr. Engel's routing model spreadsheet ("p_model_10_15.xls") and values from within his allowable ranges for each of the four coefficients (a, b, c and initial P accumulation) in this model, as described in his expert report and in his deposition.

Figure 19 shows that if the chronologies for Dr. Engel's predicted phosphorus loads to streams and rivers in the IRW for 1998-2006 are reversed, his phosphorus routing model can still be calibrated to his observed phosphorus loads to Lake Tenkiller. Specifically, Dr. Engel's predicted daily nonpoint source loads from GLEAMS plus his WWTP loads were reversed from last day to first day for each of the three subwatersheds in the IRW. Upon comparison of results in Figure 19 with those in Dr. Engel's expert report (reproduced in the top panels of Figures 15-17) it can be seen that the results for the reversed chronologies are practically the same for the Illinois River near Tahlequah (R^2 decreases from 0.974 to 0.963) and are actually improved for both Baron Fork (R^2 increases from 0.781 to 0.914) and Caney Creek (R^2 increases from 0.625 to 0.7214).

This demonstrates that Dr. Engel's models are not sensitive to the timing of his predicted daily phosphorus loads over his 9-year calibration and purported validation period from 1998 to 2006. In fact, his models produce somewhat better results when his predicted daily phosphorus loads (plus WWTP loads) are run backwards in time. Because predicted daily phosphorus loads from his GLEAMS model are driven by rainfall events, and he treated WWTP loads as daily background loads, this means that Dr. Engel's linked GLEAMS and routing models cannot tell the difference between rainy days and dry days in the IRW.

It can also be shown that wide ranges in the magnitudes of Dr. Engel's WWTP loads, and his predicted phosphorus loads from GLEAMS, can still be calibrated to his observed phosphorus loads to Lake Tenkiller by his phosphorus routing model. Figure 20 shows the ranges in each of these phosphorus load components to streams and rivers in the IRW that can still be calibrated to Dr. Engel's observed P loads to Lake Tenkiller each year from 1998 to 2006. The top panel shows results for WWTP loads to streams and rivers, and the bottom panel shows results for predicted phosphorus loads from GLEAMS to streams and rivers. Note that the phosphorus loads in this figure are shown on logarithmic scales. The vertical scales in each panel are extremely large and range from 10,000 to 1,000,000,000 lbs P/year.

For each of the three subwatersheds (Illinois, Baron Fork and Caney Creek), Dr. Engel's routing model was re-calibrated to fit these increased WWTP and GLEAMS nonpoint source loads to his observed phosphorus loads to Lake Tenkiller with R^2 values equal to or greater than those in his expert report.

In practical terms, if there were an additional 96,727,276 people in the IRW, an almost 345-fold increase, then Dr. Engel's routing model can still be calibrated to his observed phosphorus loads to Lake Tenkiller with the additional WWTP loads from this population (plus the nonpoint source phosphorus loads from GLEAMS). This WWTP load estimate is based on a human population of 280,383 in 2000 (Table 2 in Appendix B of Dr. Engel's expert report) and an annual per capita production rate of 1.298 lbs P/year which can be calculated from the information in Tables 2 and 3 of Appendix B. This example is conservative because it assumes that all of the waste generated from the additional population is untreated and that 100 percent of it is delivered directly to streams and rivers in the IRW.

Again in practical terms, if there were an additional 2,356,541,356 birds per year in the IRW, a greater than 15-fold increase, then Dr. Engel's routing model can still be calibrated to his observed phosphorus loads to Lake Tenkiller with the additional nonpoint source phosphorus loads from GLEAMS (plus Dr. Engel's WWTP loads). This estimate of additional birds is based on materials produced by Dr. Engel ("Smith00003221_New_Calculations.xls") stating that there were 151,781,155 birds (broilers, layers, pullets, turkeys) in the IRW in 2002 and that each bird produces an average of 0.0612 lb P/year. Again, this example is conservative because it assumes that all litter from these additional birds is applied to pastures and that 100 percent of the phosphorus in this litter runs off to streams and rivers.

I make no claim that the annual per capita production rate of 1.298 lbs P/year or the average annual production rate per bird of 0.0612 lb P/year are accurate, but only that these are the values that can be derived from materials produced by Dr. Engel.

These results show that the phosphorus routing model developed by Dr. Engel, when presented with a wide universe of possibilities, cannot even come close to "pinning down" the real nonpoint source runoff loads to streams and rivers in the IRW, nor can it tell the difference between Dr. Engel's WWTP loads and WWTP loads that are many times higher.

Furthermore, if Dr. Engel's routing model cannot "pin down" either of these individual phosphorus sources, then neither can it "pin down" their relative contributions. Because his model cannot tell the difference between such a large increase in a particular source, then it cannot be accurate and reliable for allocating phosphorus loads back to individual sources in the IRW.

As a final demonstration that Dr. Engel's phosphorus routing model cannot "pin down" the real phosphorus loads to streams and rivers in the IRW, I determined that it can actually be calibrated to his observed phosphorus loads to Lake Tenkiller for random inputs. Figure 21 shows predicted versus observed phosphorus loads to Lake Tenkiller in the Illinois River near Tahlequah for the calibration and purported validation results in Dr. Engel's expert report (top panel) and daily S&P 500 Stock Index values (bottom panel) for the same period (1998-2006). The R^2 values are 0.974 for both sets of results. In simple terms, Dr. Engel's routing model cannot tell the difference between phosphorus loads to streams and rivers in the IRW and stock index values.

In summary, the models developed by Dr. Engel are conceptually flawed, not scientifically credible and not reliable quantitative tools. His models can accept inputs that do not make any sense and calibrate these inputs to his observed phosphorus loads to Lake Tenkiller. Therefore, the relationships between his model inputs, which are phosphorus loads from the watershed, and his observed phosphorus loads to Lake Tenkiller make no sense.

Dr. Engel's models cannot tell the difference between rainy days and dry days in the IRW, nor can they tell the difference between his own phosphorus loads to streams and rivers, and phosphorus loads that are simply made up. When presented with a wide universe of possibilities, Dr. Engel's routing model cannot even come close to "pinning down" the real phosphorus loads to streams and rivers in the IRW, nor can it "pin down" the relative contributions of individual sources. Dr. Engel's models are not reliable quantitative tools for predicting phosphorus loads to Lake Tenkiller or the relative contributions of any individual sources to these phosphorus loads.

Supporting Statement 3b: The opinion by Dr. Engel that poultry litter land application in the IRW is a substantial contributor to phosphorus loads to Lake Tenkiller is based on model results and methods that are conceptually flawed, incorrect and not reliable.

Opinion 8 on Page 2 of Dr. Engel's expert report states that, "Poultry waste land application in the IRW is a substantial contributor (45% between 1998 and 2006 and 59% between 2003 and 2006) to P loads to Lake Tenkiller, representing the largest P source." The phosphorus allocation to each source is shown in Tables 10.14 and 10.15 on Page 93 of Dr. Engel's expert report.

First, Opinion 8 is based on results from Dr. Engel's models that are not reliable to a reasonable degree of scientific certainty. Second, even if Dr. Engel fixes all of the deficiencies in his models, as described above in my Opinion 2 and Supporting Statements 2a through 2m, and follows SERA-17 guidance, U.S. EPA recommendations on environmental models, and his own protocol for application of hydrologic/water quality models, his entire modeling framework remains conceptually flawed and inappropriate for the IRW. Third, as described below, the methods that Dr. Engel used to develop the phosphorus allocations to sources in his Opinion 8 are themselves conceptually flawed, undocumented, contain numerous errors and inconsistencies, and are not reliable to a reasonable degree of scientific certainty.

Dr. Engel's models predict only total phosphorus loads and contain no information on individual sources of phosphorus. He stated in his deposition that neither his GLEAMS nor his routing model identifies poultry litter as a phosphorus source and that this identification requires interpretation of outputs from these models after they are run. Dr. Engel uses a separate allocation method ("allocation_5_2.xls") to process and interpret the outputs from his GLEAMS and phosphorus routing models, and determine the relative contributions of individual sources to phosphorus loads to Lake Tenkiller. Despite the importance of these results in forming his Opinion 8, Dr. Engel did not include any documentation in his expert report of the methods he used for allocation of his individual phosphorus sources. He showed his answers but did not show his work.

The phosphorus loads from individual sources are combined inside Dr. Engel's models in such a way that they cannot be completely pulled apart after the models are run. The observed data are of no help because the only observed phosphorus loads that Dr. Engel used to compare with his model predictions are those for the Illinois River near Tahlequah, Baron Fork at Eldon and Caney Creek near Barber at the outlets for each of these three subwatersheds to Lake Tenkiller. The phosphorus loads at these locations are a "soup" that represent the sum of all sources in the entire watershed and cannot be used to unravel the relative contributions of any individual sources.

Not only are Dr. Engel's GLEAMS and phosphorus routing models unable to track any individual phosphorus sources, but they were constructed in a way that guarantees overestimation of the contribution of phosphorus loads from poultry litter land application. As described on Pages D-18 and D-19 of his expert report, the only phosphorus sources that Dr. Engel stated that he included in his models are animal manure (poultry, beef cattle, dairy cattle and swine), WWTP loads and commercial fertilizer. He ignored numerous other sources as described above in Supporting Statement 2d including streambank erosion, septic systems, recreational activities, nurseries, gravel mining, illegal dumping, smaller livestock facilities, wildlife, erosion from unpaved roads, land application of biosolids, and golf course fertilizer application. This means that the relative contributions of all phosphorus sources that are included in his models, including poultry litter, will be overestimated because not all of the actual phosphorus sources were included.

In Tab 2 (labeled as "Sheet 3") of his allocation spreadsheet, Dr. Engel calculated a pasture contribution of 260,983.84 lbs P by subtracting loads predicted by GLEAMS for non-pasture sources (WWTPs, crop, urban and forest) from phosphorus load to Lake Tenkiller predicted by his routing model for all sources. Dr. Engel used this pasture contribution as the basis for his phosphorus allocations to pasture in Table 10.14 and to three pasture sub-categories in Table 10.15: (1) cattle near stream only; (2) poultry only; and (3) swine, dairy, and background. The phosphorus allocations to these three pasture sub-categories are the basis for his Opinion 8 on Page 2 of his expert report.

Dr. Engel's calculation of this pasture contribution (260,983.84 lbs P) from the results of his GLEAMS and routing models is conceptually flawed and is not a reliable basis for allocations among sources. These two models predict phosphorus loads at completely different locations and one cannot simply take the difference between them. GLEAMS predicts phosphorus loads at edges-of-fields throughout the IRW, and the routing model predicts phosphorus loads delivered to Lake Tenkiller at the outlets for each of these three subwatersheds to the lake. Simply taking the difference between the phosphorus loads predicted by these two models completely ignores everything that happens "along the way" and assumes complete and instantaneous delivery of all GLEAMS edge-of-field phosphorus loads to Lake Tenkiller. In the real world this does not happen.

Even if simply taking this difference was conceptually valid, the result would not represent the pasture contribution to phosphorus loads to Lake Tenkiller. The phosphorus loads to the lake predicted by the routing model represent all sources in the IRW upstream of the last three stations before the lake, including all of the sources that Dr. Engel ignored in his GLEAMS model, whereas the phosphorus loads predicted by GLEAMS represent only the phosphorus loads from nonpoint source runoff. Consequently, simply taking the difference would represent not only the pasture contribution, but also the contributions of all the other sources that Dr. Engel ignored. These other sources are numerous and are summarized above and set forth in my Supporting Statement 2d.

Dr. Engel made an important error in specification of a key input parameter for all of his "no litter" scenarios. The input parameter RATE, which represents the total application rate of animal manure (poultry litter, dairy cattle, beef cattle and swine) to pasture land in his GLEAMS model is set to zero in all of his "no litter" scenario runs. This is not correct because only the poultry litter portion of RATE should have been set to zero, not the portions representing animal manure from dairy cattle, beef cattle and swine. This error results in overestimation of the differences between poultry litter application and no poultry litter application because the "no litter" scenarios conducted by Dr. Engel actually represent "no animal manure" scenarios. The impact of this error is an overstatement of the relative contribution of poultry litter to phosphorus loads to Lake Tenkiller.

Dr. Engel made another error by failing to separate the contribution of phosphorus loads from commercial fertilizer. Again, the impact of this error is an overstatement of the relative contribution of other sources, including poultry litter, to phosphorus loads to Lake Tenkiller.

Dr. Engel also made a unit conversion error in calculating phosphorus loads due to poultry litter and beef cattle. He calculated the phosphorus load contribution due to poultry litter plus beef cattle by subtracting the phosphorus load due to dairy cattle, swine, and background sources in units of pounds from the total phosphorus load from all sources in units of kilograms. This mismatch in units results in an error in the calculated phosphorus load contribution for poultry litter plus beef cattle and carries through in his calculation of the phosphorus load allocation attributed to only poultry litter.

Apart from simply listing conceptual flaws, errors and inconsistencies in Dr. Engel's methods, a simple example for cattle phosphorus contributions illustrates the flawed construct underlying his methods.

Dr. Engel's claims of poultry litter contributions of 45 and 59 percent to the phosphorus loads to Lake Tenkiller during 1998-2006 and 2003-2006, respectively, are very sensitive to his assumptions about cattle contributions. To develop his poultry litter contributions, Dr. Engel assumed that 35,594 lbs P/year is deposited by cattle in and near (within 10 m) of streams in the IRW (Page F-3, Engel expert report).

In his deposition Dr. Engel stated that this value of 35,594 lbs P/year does not reflect the full amount of phosphorus from cattle that is deposited onto the land in the IRW. From results on Page 109 of the expert report by Dr. Billy R. Clay, beef cattle, dairy cattle, other cattle and calves in the IRW deposit a total of 3,263,285 lbs P/year directly in flowing streams and riparian areas. Thus, the number assumed by Dr. Engel is only about 1.1 percent of the number put forth by Dr. Clay.

If the value of 35,594 lbs P/year assumed by Dr. Engel does not reflect actual conditions in the IRW, his own allocation methods can be used to see how poultry litter contributions change for different assumptions. If Dr. Engel's assumed value is doubled to 71,188 lbs P/year, a value that is only 2.2 percent of Dr. Clay's value, then Dr. Engel's allocation method calculates that poultry litter contributions to phosphorus loads to Lake Tenkiller would be 38 and 53 percent, respectively, for 1998-2006 and 2003-2006. If Dr. Engel's assumed value is increased five-fold to 177,970 lbs P/year, about 5.5 percent of Dr. Clay's value, his allocation method calculates contributions of 19 and 35 percent, respectively, for the two periods. Finally, if Dr. Engel's assumed value is increased 11-fold to 391,534 lbs P/year, about 12 percent of Dr. Clay's value, his allocation method calculates that contributions of poultry litter to phosphorus loads to Lake Tenkiller become approximately zero for both time periods. Actually, Dr. Engel's allocation method produces negative percentages for both time periods, but these results are not meaningful and are a consequence of the flawed construct underlying his methods.

I make no claim that my assumptions or calculations reflect actual conditions in the IRW, but only that they illustrate the sensitivity of the claims in Dr. Engel's Opinion 8 to his assumptions about the contributions of cattle to phosphorus loads to Lake Tenkiller.

Not only is Dr. Engel's Opinion 8 undermined by the above flaws and errors in both his methods and his results, it is also inconsistent with results in other parts of his expert report. In Table 10.4 on Page 55 of his expert report, Dr. Engel presents differences in phosphorus loads to Lake Tenkiller for continued poultry litter application versus poultry litter application cessation for the next 100 years. These differences in phosphorus loads are presented for 10-year periods and represent the contributions of poultry litter land application in the IRW predicted by Dr. Engel's models for each 10-year period.

For the first 10-year period the results in Table 10.4 indicate that poultry litter land application in the IRW represents 16.1 percent of the phosphorus loads to Lake Tenkiller. In Table 10.4 on Page 11 of his errata dated September 4, 2008, Dr. Engel revised this number to 18.3 percent. Dr. Engel provides no explanation of the differences between this 18.3 percent contribution for 1997-2006 and the 45 and 59 percent contributions for 1998-2006 and 2003-2006, respectively, in his Opinion 8 on Page 2 of his expert report. Dr. Engel does not explain how poultry litter phosphorus can account for 45 or 59 percent of the phosphorus loads to Lake Tenkiller when his model results show that cessation of poultry litter application produces only an 18.3 percent improvement.

Finally, Opinion 8 in Dr. Engel's expert report is inconsistent with the revised predicted phosphorus loads to Lake Tenkiller in his errata of September 4, 2008. The allocation methods that Dr. Engel used to determine the relative contribution of poultry litter to phosphorus loads to Lake Tenkiller rely upon outputs from both his GLEAMS and phosphorus routing models. The revised predicted phosphorus loads to Lake Tenkiller in Dr. Engel's September 4, 2008, errata were calculated using a different version of the phosphorus routing model from the one he used in his expert report. Consequently, the phosphorus allocations in Tables 10.14 and 10.15, and in Opinion 8, all should have been revised as well. In his errata of September 4, 2008, Dr. Engel did not revise Tables 10.14 or 10.15, or his Opinion 8, nor did he produce a revised version of the methods in his original allocation spreadsheet.

In summary, the claim by Dr. Engel in his Opinion 8 that poultry litter land application in the IRW is a substantial contributor to phosphorus loads to Lake Tenkiller is based on methods and results that are conceptually flawed, undocumented, contain numerous errors and inconsistencies, and are not reliable to a reasonable degree of scientific certainty.

4. The flawed and unreliable results put forth by Dr. Engel, and relied upon by other Plaintiffs' experts, create a domino effect and render the opinions of these other experts flawed and unreliable to the extent that they relied upon his results.

Supporting Statement 4a: The total phosphorus loads to Lake Tenkiller calculated by Dr. Engel for Dr. Wells to use for calibrating his model of Lake Tenkiller are incorrect; consequently, this calls into question Dr. Wells' entire model calibration.

The CE-QUAL-W2 model used by Dr. Wells for Lake Tenkiller requires input loadings for total phosphorus. The calibration period that Dr. Wells used for his model was 2005, 2006 and the first nine months of 2007. The years 2005 and 2006 overlapped the last two years for which Dr. Engel purported to validate his GLEAMS and routing models.

Dr. Engel provided input loadings for total phosphorus to Dr. Wells but he did not provide the phosphorus loadings predicted by his own models for 2005 or 2006, nor did he extend his models to include the first nine months of 2007. Instead, he used the LOADEST program developed by USGS and observed flows and total phosphorus concentrations for the Illinois River near Tahlequah, Baron Fork and Caney Creek locations to calculate his total phosphorus loads for Dr. Wells.

The observed total phosphorus loads that Dr. Engel provided to Dr. Wells for 2005 and 2006 are inconsistent with both the observed total phosphorus loads in Table 5.3 of Dr. Engel's expert report and those in his routing model spreadsheet ("p_model_10_15.xls"). This means that Dr. Engel and Dr. Wells each used different observed total phosphorus loads to Lake Tenkiller for 2005 and 2006 to calibrate their respective models.

In addition, the observed total phosphorus loads that Dr. Engel provided to Dr. Wells are incorrect. I calculated the observed total phosphorus loads that Dr. Engel should have calculated, given the correct primary data for total phosphorus concentrations and my understanding of the method he used. Again, I used Model 8 in the LOADEST program and the AMLE method as described above in Supporting Statement 2k.

Figure 22 shows differences, relative to the correct observed loads, for the total phosphorus loads calculated by Dr. Engel for Dr. Wells to use in his model of Lake Tenkiller. Results are shown for observed total phosphorus loads for each of the three subwatersheds and the entire IRW for 2005, 2006 and the first nine months of 2007. Dr. Engel's values for observed total phosphorus loads range from 95 to 150 percent of the correct values among the individual subwatershed-time period combinations, and from 105 to 110 percent among the three different time periods.

Appendix C contains detailed results for the Illinois River near Tahlequah, Baron Fork at Eldon, Caney Creek near Barber, and for all three subwatersheds combined.

The total phosphorus loads that Dr. Engel provided to Dr. Wells for calibration of model for Lake Tenkiller are overestimated by 5 to 10 percent. The degree to which model outputs are accurate and reliable depends on the degree to which model inputs represent real-world conditions in the system being modeled. Dr. Wells' model calibration is based on model inputs that exceed reality, thus calling into question his entire set of model calibration results.

<u>Supporting Statement 4b:</u> The loads of dissolved ortho phosphate to Lake Tenkiller calculated by Dr. Engel for Dr. Wells to use for calibrating his model of Lake Tenkiller are based on the wrong form of phosphorus, which further calls into question Dr. Wells' entire model calibration.

In addition to total phosphorus, the CE-QUAL-W2 model used by Dr. Wells for Lake Tenkiller also requires input loadings for dissolved ortho phosphate (PO_4), the form directly taken up by algae. Following the terminology discussed below, I will refer to this form of phosphorus as soluble reactive phosphorus (SRP) throughout my expert report. Dr. Engel provided input loadings for SRP to Dr. Wells, but he used observed data for the wrong form of phosphorus and substantially overestimated the correct loads.

The following description of phosphorus forms was excerpted from material sponsored by Kent State University at http://dipin.kent.edu/Phosphorus.htm. Phosphorus in natural waters consists of three component parts: soluble reactive phosphorus (SRP), soluble organic phosphorus (SOP) and particulate phosphorus (PP). The sum of SRP and SOP is called soluble phosphorus (SP), and the sum of all phosphorus components is called total phosphorus (TP). Soluble and particulate phosphorus are differentiated by whether or not they pass through a 0.45 micron membrane filter.

Soluble reactive phosphorus (SRP) consists largely of the inorganic orthophosphate (PO_4) form of phosphorus. Orthophosphate is the phosphorus form that is directly taken up by algae. At one time SRP was called "dissolved inorganic phosphorus" but this terminology was changed to "soluble reactive phosphorus" to reflect a more realistic interpretation of what forms of phosphorus were found in this fraction.

The input loads for SRP that Dr. Engel calculated and provided to Dr. Wells are incorrect for two reasons. First, Dr. Engel used data for soluble phosphorus (SP) concentrations not SRP concentrations. He used phosphorus concentration data corresponding to USGS Code P00666 (Phosphorus, water, filtered, milligrams per liter) instead of USGS Code P00671 (Orthophosphate, water, filtered, milligrams per liter as phosphorus). This is a substantial misrepresentation because, although SP includes SRP, it also includes SOP, a phosphorus form that is not directly taken up by algae.

Second, the loads Dr. Engel calculated using the available data for USGS flows and SP concentrations are incorrect due to many other errors. Figure 23 shows differences, relative to the correct (SRP) observed loads, for the SP loads actually calculated by Dr. Engel for Dr. Wells to use in his model of Lake Tenkiller for each subwatershed and the whole IRW. These differences are significant because the incorrect loads Dr. Engel calculated and provided to Dr. Wells for his Lake Tenkiller model are substantially higher than the SRP loads that should have been provided. The loads Dr. Engel provided for 2005, 2006 and the first nine months of 2007 are 29, 22 and 20 percent higher, respectively, than the correct SRP values.

Appendix C contains detailed results for the Illinois River near Tahlequah, Baron Fork at Eldon, Caney Creek near Barber, and for all three subwatersheds combined.

As discussed above in Supporting Statement 4a, the total phosphorus loads that Dr. Engel provided to Dr. Wells for calibration of his model of Lake Tenkiller are overestimated by 5 to 10 percent. To compound this error, the SRP loads he provided are also overestimated, but by an even larger amount, 20 to 29 percent. Again, the degree to which model outputs are accurate and reliable depends on the degree to which model inputs represent real-world conditions in the system being modeled. Again, Dr. Wells' model calibration is based on model inputs that exceed reality, thus further calling into question his entire set of model calibration results.

These model input errors for total phosphorus and SRP loads are especially significant because phosphorus loads to Lake Tenkiller, and the relative contribution of poultry litter to these loads, are central to the Plaintiffs' claims in this case. The overstatement of both sets of phosphorus loads in Dr. Wells' model, especially the SRP form, is significant because it means the algae in his model "see" too much phosphorus, thus calling into question the accuracy and reliability of his model for predicting the relationship between P loads to Lake Tenkiller and conditions in the lake.

<u>Supporting Statement 4c:</u> The results for simulations of future phosphorus loads to Lake Tenkiller that Dr. Engel provided to Dr. Wells are flawed and unreliable; consequently, all of Dr. Wells' results that link future phosphorus loads to future conditions in the lake are also flawed and unreliable.

Dr. Engel also provided model outputs from his simulations of future phosphorus loads to Lake Tenkiller for Dr. Wells to use as inputs to his model of the lake. Because all of the model results that Dr. Engel provided to Dr. Wells are flawed and unreliable, all of Dr. Wells' results that link future phosphorus loads to future conditions in Lake Tenkiller are also flawed and unreliable.

Dr. Wells used his calibrated model of Lake Tenkiller to conduct the following simulations linking future phosphorus loads to conditions in the lake for the next 50 years:

- Base
- Cessation (historical sediment oxygen demand reduction)
- Cessation (historical sediment oxygen demand immediate reduction)
- Natural conditions
- Growth conditions
- Historical conditions with hydrology from 1950 to 1999

These future simulations are described on Pages 138 and 139 in Dr. Wells' expert report. The results for future conditions in Lake Tenkiller from all of these simulations are flawed and unreliable.

<u>Supporting Statement 4d:</u> The results for simulations of future phosphorus loads that Dr. Engel provided to Dr. Stevenson are flawed and unreliable; consequently, all of Dr. Stevenson's results that link future phosphorus concentrations to future conditions in streams and rivers in the IRW are also flawed and unreliable.

Dr. Stevenson developed relationships between phosphorus concentrations in streams and rivers in the IRW and future conditions in these streams and rivers. He used observations for 2006 as his base conditions and results for simulations of future phosphorus loads from Dr. Engel's models to develop estimates of phosphorus concentrations in streams and rivers for the next 50 years. Because all of the model results that Dr. Engel provided to Dr. Stevenson are flawed and unreliable, all of Dr. Stevenson's results that link future phosphorus concentrations to future conditions in streams and rivers in the IRW are also flawed and unreliable.

Dr. Stevenson used the relationships he developed to put forth results for the following future scenarios:

- Control
- No litter
- No litter plus buffer
- Continued growth

These future scenarios are described on Pages 44-45 of Dr. Stevenson's expert report. The results for all of these future scenarios are flawed and unreliable.

SUMMARY OF OPINIONS AND SUPPORTING STATEMENTS ON EXPERT REPORT BY DR. SCOTT WELLS

1. **The incorrect phosphorus loads provided by Dr. Engel, and relied upon by Dr. Wells, call into question Dr. Wells' entire model calibration.**

    a. The total phosphorus loads to Lake Tenkiller calculated by Dr. Engel for Dr. Wells to use in calibrating his model for Lake Tenkiller are incorrect; consequently, this calls into question Dr. Wells' entire model calibration.

    b. The loads of soluble reactive phosphorus (SRP) to Lake Tenkiller calculated by Dr. Engel for Dr. Wells to use in calibrating his model for Lake Tenkiller are based on the wrong form of phosphorus, which further calls into question Dr. Wells' entire model calibration.

2. **The methods that Dr. Wells used in applying his model to Lake Tenkiller are inconsistent with generally accepted practices in the scientific community.**

    a. The version of the CE-QUAL-W2 model used by Dr. Wells for Lake Tenkiller was not the current, documented, public domain version but instead was a beta version that was not completely tested or documented.

    b. The computer program for the CE-QUAL-W2 model used by Dr. Wells for his expert report is unstable, unreliable and contains a serious inherent flaw of unknown origin.

    c. The model developed by Dr. Wells substantially over-predicts the relative proportions of blue-green algae in Lake Tenkiller, the algal group of greatest concern.

    d. Dr. Wells did not follow U.S. Environmental Protection Agency guidance on environmental models.

    e. Dr. Wells did not follow his own published guidance on use and misuse of water quality models in environmental disputes.

3. **The flawed and unreliable modeling results put forth by Dr. Wells, and relied upon by other Plaintiffs' experts, render the opinions of these other experts flawed and unreliable to the extent that they relied upon his results.**

    a. The results for simulations of future phosphorus and dissolved oxygen concentrations in Lake Tenkiller that Dr. Wells provided to Drs. Cooke and Welch are flawed and unreliable; consequently, all of their results that link future phosphorus and dissolved oxygen concentrations in the lake to future conditions in the lake are also flawed and unreliable.

OPINIONS AND SUPPORTING STATEMENTS ON EXPERT REPORT BY DR. SCOTT WELLS

1. The incorrect phosphorus loads provided by Dr. Engel, and relied upon by Dr. Wells, call into question Dr. Wells' entire model calibration.

Supporting Statement 1a: The total phosphorus loads to Lake Tenkiller calculated by Dr. Engel for Dr. Wells to use in calibrating his model for Lake Tenkiller are incorrect; consequently, this calls into question Dr. Wells' entire model calibration.

The CE-QUAL-W2 model used by Dr. Wells for Lake Tenkiller requires input loadings for total phosphorus. The calibration period that Dr. Wells used for his model was 2005, 2006 and the first nine months of 2007. The years 2005 and 2006 overlapped the last two years for which Dr. Engel calibrated and purported to validate his GLEAMS and routing models.

Dr. Engel provided input loadings for total phosphorus to Dr. Wells but he did not provide the phosphorus loadings predicted by his own models for 2005 or 2006, nor did he extend these models to include the first nine months of 2007. Instead, he used the LOADEST program developed by the USGS and observed flows and total phosphorus concentrations for the Illinois River near Tahlequah, Baron Fork and Caney Creek gaging stations.

The observed total phosphorus loads that Dr. Engel provided to Dr. Wells are incorrect. I calculated the observed total phosphorus loads that Dr. Engel should have calculated, given the correct primary data for total phosphorus concentrations and my understanding of the method he used. Again, I used Model 8 in the LOADEST program and the AMLE method as described above in Supporting Statement 4a under my opinions on the expert report by Dr. Engel.

Figure 22 shows differences, relative to the correct observed loads, for the total phosphorus loads calculated by Dr. Engel for Dr. Wells to use in his model of Lake Tenkiller. Results are shown for observed total phosphorus loads for each of the three subwatersheds and the entire IRW for 2005, 2006 and the first nine months of 2007. Dr. Engel's values for observed total phosphorus loads range from 95 to 150 percent of the correct values among the individual subwatershed-time period combinations, and from 105 to 110 percent among the three different time periods.

Appendix C contains detailed results for the Illinois River near Tahlequah, Baron Fork at Eldon, Caney Creek near Barber, and for all three subwatersheds combined.

The total phosphorus loads that Dr. Wells used to calibrate his model for Lake Tenkiller are overestimated by 5 to 10 percent. The degree to which model outputs are accurate and reliable depends on the degree to which model inputs represent real-world conditions in the system being modeled. Dr. Wells' model calibration is based on model inputs that exceed reality, thus calling into question his entire set of model calibration results.

Supporting Statement 1b: The loads of soluble reactive phosphorus (SRP) to Lake Tenkiller calculated by Dr. Engel for Dr. Wells to use in calibrating his model for Lake Tenkiller are based on the wrong form of phosphorus, which further calls into question Dr. Wells' entire model calibration.

In addition to total phosphorus loads, the CE-QUAL-W2 model used by Dr. Wells for Lake Tenkiller also requires input loadings for SRP (described as dissolved ortho phosphate by Dr. Wells), the form directly taken up by algae. Dr. Engel also provided input loadings for SRP to Dr. Wells for calibration of his Lake Tenkiller model.

The following description of phosphorus forms was excerpted from material sponsored by Kent State University at http://dipin.kent.edu/Phosphorus.htm. Phosphorus in natural waters consists of three component parts: soluble reactive phosphorus (SRP), soluble organic phosphorus (SOP) and particulate phosphorus (PP). The sum of SRP and SOP is called soluble phosphorus (SP), and the sum of all phosphorus components is called total phosphorus (TP). Soluble and particulate phosphorus are differentiated by whether or not they pass through a 0.45 micron membrane filter.

Soluble reactive phosphorus (SRP) consists largely of the inorganic orthophosphate (PO_4) form of phosphorus. Orthophosphate is the phosphorus form that is directly taken up by algae. At one time SRP was called "dissolved inorganic phosphorus" but this terminology was changed to "soluble reactive phosphorus" to reflect a more realistic interpretation of what forms of phosphorus were found in this fraction.

The input loads for SRP that Dr. Engel calculated and provided to Dr. Wells are incorrect for two reasons. First, Dr. Engel used data for soluble phosphorus (SP) concentrations not SRP concentrations. He used phosphorus concentration data corresponding to USGS Code P00666 (Phosphorus, water, filtered, milligrams per liter) instead of USGS Code P00671 (Orthophosphate, water, filtered, milligrams per liter as phosphorus). This is a substantial misrepresentation because, although SP includes SRP, it also includes SOP, a phosphorus form that is not directly taken up by algae.

Second, the loads Dr. Engel calculated using the LOADEST program and the available data for USGS flows and SP concentrations are incorrect due to many other errors. Figure 23 shows the differences, relative to the correct (SRP) observed loads, for the SP loads actually calculated by Dr. Engel for Dr. Wells to use in his model of Lake Tenkiller. These differences are significant because the incorrect loads Dr. Engel calculated and provided to Dr. Wells are substantially higher than the SRP loads that should have been provided. The loads Dr. Engel provided for 2005, 2006 and the first nine months of 2007 are 29, 22 and 20 percent higher, respectively, than the correct SRP values.

Appendix C contains detailed results for the Illinois River near Tahlequah, Baron Fork at Eldon, Caney Creek near Barber, and for all three subwatersheds combined.

As discussed above in Supporting Statement 1a, the total phosphorus loads that Dr. Wells used to calibrate his model are overestimated by 5 to 10 percent. To compound this error, the SRP loads he used are also overestimated, but by an even larger amount, 20 to 29 percent. Again, the degree to which model outputs are accurate and reliable depends on the degree to which model inputs represent real-world conditions in the system being modeled. Again, Dr. Wells' model calibration is based on model inputs that exceed reality, thus further calling into question his entire set of model calibration results.

These model input errors for total phosphorus and SRP are significant because phosphorus loads to Lake Tenkiller, and the relative contribution of poultry litter to these loads, are central to the Plaintiffs' claims in this case. The overstatement of both sets of phosphorus loads in Dr. Wells' model, especially the SRP form, is significant because it means the algae in his model "see" too much phosphorus, thus calling into question the accuracy and reliability of his model for predicting the relationship between phosphorus loads to Lake Tenkiller and conditions in the lake.

In fact, the results in Figure 138 on Page 55 of Dr. Wells' second errata indicate that his model predictions overestimate the observed algae concentrations in the lake. For the lake as a whole, concentrations of chlorophyll a, an indicator of total algal biomass concentration, predicted by Dr. Wells' model are biased 8 percent higher than observed concentrations. Furthermore, this bias is not uniform throughout the lake. Dr. Wells' model predictions are more highly biased in the lower portion of the lake near Tenkiller Dam than they are in the upper portion near the inputs from the Illinois River, Baron Fork and Caney Creek. These results call into question the accuracy and reliability of Dr. Wells' model for predicting the relationship between phosphorus loads to Lake Tenkiller and the amount of algae in the lake.

2. The methods that Dr. Wells used in applying his model to Lake Tenkiller are inconsistent with generally accepted practices in the scientific community.

Supporting Statement 2a: The version of the CE-QUAL-W2 model used by Dr. Wells for Lake Tenkiller was not the current, documented, public domain version but instead was a beta version that was not completely tested or documented.

The term "beta version" refers to software that has passed the initial testing stage and has been released to a limited number of users for further testing before its official release. Beta testing allows new software to undergo usability testing and provides the opportunity for users to provide feedback so that any malfunctions in the software can be reported back to the developers and fixed. Beta versions of software can be unstable or unreliable.

Dr. Wells applied the CE-QUAL-W2 water quality model to Lake Tenkiller. All of the results in his expert report of May, 2008, are based on Version 3.6 of this model which, at the time he conducted his work, was a beta version. This version was not fully vetted by the scientific or the user communities, and was not fully documented. He did not use Version 3.5 which was the current, documented, official version available at that time.

Dr. Wells produced his first errata in August, 2008, and his second errata on September 22, 2008. Version 3.6 of CE-QUAL-W2 was officially released on December 4, 2008. In his produced materials that accompanied his two errata, Dr. Wells did not include updated versions of the CE-QUAL-W2 model code or executables.

On page 14 of the U.S. EPA (2008) guidance on environmental models it states, *"Model coding (sic) translates the mathematical equations that constitute the model framework into functioning computer code. Code verification (sic) ascertains that the computer code has no inherent numerical problems with obtaining a solution."* The model coding and code verification for the beta version of the model used by Dr. Wells for Lake Tenkiller were not completed, thus the impacts on his model results were not established and are unknown.

Supporting Statement 2b: The computer program for the CE-QUAL-W2 model used by Dr. Wells for his expert report is unstable, unreliable and contains a serious inherent flaw of unknown origin.

A computer program that is correctly developed and tested should be stable, reliable and capable of producing identical results when it is run consecutively with the same input data. The computer program for the CE-QUAL-W2 model used by Dr. Wells for his expert report fails to produce identical results for consecutive runs with the same input data. Furthermore, the results from multiple consecutive runs with this program are spurious and cannot be replicated.

The computer program used by Dr. Wells is unstable, unreliable, and contains a serious inherent flaw of unknown origin. It is impossible to know the error rate because we get different answers each time we run the same model with the same input data. Furthermore, because we get different answers each time, we do not even know the baseline. This flaw in the computer program precludes the ability to reproduce the results in Dr. Wells' expert report and its impact on his results was not established, is impossible to predict, and is unknown.

No model whose results cannot be replicated would ever be accepted in the scientific community, even if it was only off by just a few percent. The lack of ability to successfully replicate would call into question the inherent accuracy and reliability of the model.

Supporting Statement 2c: The model developed by Dr. Wells substantially over-predicts the relative proportions of blue-green algae in Lake Tenkiller, the algal group of greatest concern.

The biomass of blue-green algae (cyanobacteria) is important to the Plaintiffs' claims pertaining to conditions in Lake Tenkiller. In their joint expert report for the Plaintiffs, Drs. G.D. Cooke and E.B. Welch used concentrations of blue-green algae in Lake Tenkiller as indicators of water quality, and related these indicators to phosphorus concentrations in the lake.

Dr. Wells acknowledged that algal biomass was important for his model calibration. In his E-mail on 12/20/07 to Roger Olsen and Robert van Waasbergen, with a copy to David Page, he stated that, *"In looking at the data, I have a question on the 'algae biomass dry weight in mg/l' in the database. These are invaluable data in comparing it to the more common chlorophyll a data – since the model uses algae as dry weight biomass."*

Dr. Wells also acknowledged that biomass for individual algal groups was important for his model calibration. In his E-mail on 1/15/08 to Eugene Welch, he stated that, *"I will eventually* *use 3 algal groups - this run only has one general group of phytoplankton. Have you put together any summaries of the algae species/succession in Tenkiller? Let me know if you need some further background on the model output."*

The Plaintiffs collected 436 samples for algal abundance between 5/17/05 and 9/26/06 at four stations in Lake Tenkiller. They also collected 372 samples for algal biomass between 3/28/06 and 9/26/06 at these same stations. These samples included biomass for blue-green algae.

In his expert report, Dr. Wells did not present results for any comparisons between his model predictions and the available data in Lake Tenkiller for either total algal biomass or algal biomass for any individual groups. His failure to do so is an important deficiency in his model calibration. However, his produced materials indicate that he did conduct comparisons between his model predictions for the relative proportions of his three algal groups and observed data for average conditions from May to September, for 2006 and 2007, at Stations LK04 (upstream end) and LK01 (downstream end) in Lake Tenkiller.

Figures 24 and 25 are the results of these comparisons using Dr. Wells' produced materials dated 1/25/08 and Figures 26 and 27 are the results using his produced materials dated 5/21/08. Figures 28 and 29 are results of comparisons that I made using the model outputs from Run 200 in Dr. Wells' expert report of May, 2008, and Figures 30 and 31 are results of comparisons I made using the model outputs from Run 400 in Dr. Wells' second errata dated September 22, 2008.

First, all of these predictions from Dr. Wells' model substantially misrepresent the proportions of the individual algal groups actually observed in Lake Tenkiller, especially the blue-green group. This should have caused Dr. Wells to call into question the accuracy and reliability of his model. Second, Dr. Wells failed to disclose these results in his expert report or to Drs. Cooke or Welch, even though they put forth opinions on blue-green algae in Lake Tenkiller.

Inspection of the results in Figures 24-31 reveals that at Station LK04, Dr. Wells' model predicts that blue-green algae represent 58 to 98 percent of the total algal biomass in 2006, and 71 to 97 percent in 2007. The observed values are 31 and 55 percent, respectively. At Station LK01, Dr. Wells' model predicts that blue-green algae represent 55 to 93 percent of the total algal biomass in 2006. The observed value is 33 percent. In 2007, Dr. Wells' model results for 1/25/08, 5/21/08 and Run 200 in his expert report predict that blue-green algae represent 28 to 72 percent of the total algal biomass. The observed value is 25 percent.

There are 16 different combinations of model-data comparisons among the results in Figures 24-31 that correspond to two sampling stations, two years, and four model runs. The only one of these 16 comparisons in which Dr. Wells' model predicts a lower proportion of blue-green algae than are actually observed in Lake Tenkiller is for Station LK01 in 2007 for Run 400 in his second errata. Results from that run predict that blue-green algae represent zero percent of the total biomass, whereas the actual observed value is 25 percent.

In summary, for 15 out of 16 model-data comparisons, Dr. Wells' model substantially over-predicts the relative proportions of blue-green algae in Lake Tenkiller, the algal group of greatest concern. The results from Dr. Wells' model for this important algal group are inaccurate and unreliable, and should have caused Dr. Wells' to call into question his model calibration.

As discussed above in Supporting Statement 1b, the overstatement of both sets of phosphorus loads in Dr. Wells' model, especially the SRP form, is significant because it means the algae in his model "see" too much phosphorus. Also, the concentrations of total algae predicted by Dr. Wells' model are overestimated, especially in the lower portion of the lake near Tenkiller Dam. These errors are now compounded because not only are the concentrations of total algae in Dr. Wells' model overestimated, but the relative proportions of blue-green algae, the algal group of greatest concern, are substantially overestimated in his model predictions.

The cumulative impact of these errors means that Dr. Wells' model is not an accurate and reliable tool for predicting the relationship between phosphorus loads from the IRW and algae in Lake Tenkiller, especially blue-green algae, the algal group of greatest concern. When confronted with data for this important group of algae, his model predictions simply do not correspond to observations in the lake.

Supporting Statement 2d: Dr. Wells did not follow U.S. Environmental Protection Agency guidance on environmental models.

U.S. EPA (2008) recommends conducting sensitivity analyses to characterize the most and least important sources of uncertainty in environmental models. Sensitivity analysis investigates how model outputs are affected by changes in selected model inputs. Dr. Wells presented no results for sensitivity analyses to evaluate the impacts of changes in any of his hydrodynamic or water quality model parameters. Consequently, the impacts of uncertainties in his model calibration parameters on his model results were not established and are unknown.

Supporting Statement 2e: Dr. Wells did not follow his own published guidance on use and misuse of water quality models in environmental disputes.

Dr. Wells presented a paper entitled, "Surface Water Hydrodynamics and Water Quality Models: Use and Misuse" at the 23rd Annual Water Law Conference, San Diego, CA, February 24-25, 2005. In that paper he covered topics that included examples of model misuse and the fallacy of validation.

On Page 7 of his paper Dr. Wells states that *" ... an honest modeling study will show all model-data comparisons of the model predictions and field data."* Despite this, his model included predictions of biomass concentrations for three individual algal groups and data were available for all three of these groups, but his expert report did not contain model-data comparisons for any of these three groups.

Also on Page 7 of his paper, Dr. Wells states that *"A well-thought out report would then have graphical and statistical summaries of all calibration field data."* Tables 5, 6, and 9 in his expert report contained summaries of model-data error statistics for water level, temperature and dissolved oxygen, respectively, he did not show similar tables for any other calibration field data.

On Page 9 of his paper, Dr. Wells states that *"All field data (that pass a QA/QC check) should be compared to model results."* As described in the expert report by Dr. Roger Olsen, algal group biomass data were collected by the Plaintiffs in Lake Tenkiller, in accordance with the QA/QC procedures documented therein. Dr. Wells did not show any comparisons between his model predictions and these field data in his expert report. If he had done so, the results of these comparisons would have been a basis for calling into question the accuracy and reliability of his model predictions.

Also on Page 9 of his paper, Dr. Wells states that, *"For a dynamic model, model predictions and field data should be shown graphically and statistically on an instantaneous basis."* The CE-QUAL-W2 model that Dr. Wells applied to Lake Tenkiller is a dynamic model. Dr. Wells did not show any graphical results for water temperature on an instantaneous basis in his expert report. Furthermore, he did not show any model-data statistics on an instantaneous basis for total nitrogen, dissolved nitrate plus nitrite nitrogen, dissolved ammonia nitrogen, total phosphorus, ortho phosphorus, chlorophyll or underwater light attenuation in his expert report.

3. The flawed and unreliable modeling results put forth by Dr. Wells, and relied upon by other Plaintiffs' experts, render the opinions of these other experts flawed and unreliable to the extent that they relied upon his results.

<u>Supporting Statement 3a</u>: **The results for simulations of future phosphorus and dissolved oxygen concentrations in Lake Tenkiller that Dr. Wells provided to Drs. Cooke and Welch are flawed and unreliable, consequently, all of their results that link future phosphorus and dissolved concentrations in the lake to future conditions in the lake are also flawed and unreliable.**

Dr. Engel provided model outputs from his simulations of future phosphorus loads to Lake Tenkiller for Dr. Wells to use as inputs to his model of the lake. In addition to the deficiencies caused by the incorrect input loads for total phosphorus and SRP provided by Dr. Engel discussed above in Supporting Statements 1a and 1b, and Dr. Wells' own flaws and errors discussed above in Supporting Statements 2a through 2e, the flaws in Dr. Wells' model are further compounded by the flawed results from Dr. Engel's models for simulations of future phosphorus loads to Lake Tenkiller. This means that all of Dr. Wells' results that link future phosphorus loads to conditions in Lake Tenkiller are also flawed and unreliable.

In their joint expert report, Drs. G. D. Cooke and E.B. Welch use concentrations of total phosphorus (TP) and dissolved oxygen in Lake Tenkiller as indicators of water quality. Throughout their expert report, Drs. Cooke and Welch put forth opinions on future conditions in Lake Tenkiller that rely upon predictions of future TP and dissolved oxygen concentrations in the lake from Dr. Wells' model. Because the predictions provided by Dr. Wells are flawed and unreliable, all of the opinions put forth by Drs. Cooke and Welch that relied upon these predictions are also flawed and unreliable.

OPINIONS ON EXPERT REPORT BY DR. JAN STEVENSON

1. The results for simulations of future phosphorus loads that Dr. Engel provided to Dr. Stevenson are flawed and unreliable; consequently, all of Dr. Stevenson's results that link future phosphorus concentrations to future conditions in streams and rivers in the IRW are also flawed and unreliable.

Dr. Stevenson developed relationships between total phosphorus (TP) concentrations in streams and rivers in the IRW and future conditions in these streams and rivers. He used observations for 2006 as his base conditions and results for simulations of future phosphorus loads from Dr. Engel's models to develop estimates of TP concentrations in streams and rivers in 50 years. Dr. Stevenson used the relationships he developed to put forth results for the following future scenarios:

- Control
- No litter
- No litter plus buffer
- Continued growth

Because all of the model results that Dr. Engel provided to Dr. Stevenson are flawed and unreliable, all of Dr. Stevenson's results that link future TP concentrations in streams and rivers in the IRW to future conditions are also flawed and unreliable.

2. Dr. Stevenson used results for simulations of future phosphorus loads from Dr. Engel's models that are far downstream in the IRW from the third-order subwatersheds in his analysis.

Not only did Dr. Stevenson use model results from Dr. Engel that are flawed and unreliable, but these model results do not even correspond to the locations at which Dr. Stevenson conducted his analysis. As described on Page 43 of his expert report, Dr. Stevenson conducted his future scenarios for 96 of the 336 third-order subwatersheds in the IRW. However, all of the predictions from Dr. Engel's models correspond to only the last three stations before Lake Tenkiller in the Illinois River near Tahlequah, Baron Fork at Eldon and Caney Creek near Barber. These stations are far downstream from the locations at which Dr. Stevenson conducted his analysis.

Figure 32 is map of the locations of the Plaintiffs' sampling stations in third-order streams for summer 2006. The Plaintiffs collected samples at 215 locations in 96 third-order subwatersheds, which were a subset of the 336 third-order subwatersheds that were accessible by road. Dr. Stevenson used results from these samples for his analysis. The distance from Tahlequah to the furthest upstream station sampled by the Plaintiffs on a third-order stream is 103 miles. This station is located on Sweetwater Creek at the headwaters of the Illinois River south of Prairie Grove.

Dr. Stevenson assumed that TP concentrations in all of his third-order streams would change by the same amount, and in the same direction, as the changes in Dr. Engel's predicted phosphorus loads to Lake Tenkiller in the Illinois River near Tahlequah, Baron Fork at Eldon and Caney Creek near Barber. That is, if phosphorus load to Lake Tenkiller declines by 50 percent at Tahlequah, then Dr. Stevenson assumed that this 50 percent change applies to all third-order stream locations in the Illinois River watershed. He assumed this change applies regardless of differences in how individual third-order streams are influenced by local land use types or phosphorus sources.

The three outlet stations just before Lake Tenkiller are not proper surrogates for Dr. Stevenson's analysis of third-order streams back up in the watershed. Dr. Stevenson ignored the enormous size of the watershed, the distance between poultry litter application sites and third-order streams, and everything that happens "along the way" between these third-order streams and the three outlet stations. The Illinois River and Baron Fork are sixth-order streams. They are not surrogates for third-order streams.

In addition, Dr. Stevenson did not even link his 96 subwatersheds to their corresponding downstream stations in the Illinois, Baron Fork or Caney Creek subwatersheds. Instead, he used flow-weighted averages of the percent changes in Dr. Engel's predicted phosphorus loads for these three subwatersheds. That is, he combined all three of these subwatersheds together and applied the same percent changes to all of his 96 subwatersheds.

3. Dr. Stevenson abandons the method he uses for future phosphorus concentrations in streams and rivers in the IRW in his expert report but he provides no basis for doing so.

In his first errata on August 5, 2008, Dr. Stevenson abandoned the linear-regression method he used in his expert report to determine percent changes in TP concentrations over the next 50 years, and adopted instead a method using long-term averages of TP concentrations. Dr. Stevenson did not claim that he made any errors in his original expert report. He simply stated that his original method was not as accurate as his new method but provided no statistical analyses or any other evidence to support this claim. When he used his new method, an inconsistency in his original expert report disappeared.

On Page 45 of his expert report, Dr. Stevenson stated, *"The percent reduction in TP concentrations was successively higher for the control (-12 percent), no litter plus buffer (-27 to -30 percent), and no litter (-33 to -36 percent) scenarios."*

These results are internally inconsistent because they indicate that the "no litter plus buffer" scenario would produce higher TP concentrations than the "no litter" alone scenario. These results are also at odds with the summaries of the phosphorus loads on Page 92 in Dr. Engel's expert report. Dr. Engel's results for predicted phosphorus loads to Lake Tenkiller are lower for the "no litter plus buffer" scenario than for the "no litter" scenario. Dr. Stevenson offered no explanation for these inconsistencies except to state on Page 45 of his expert report that, *"Discussion of reasons for differences in reductions of average seasonal TP concentrations among these scenarios was beyond the scope of this report."*

Using this new method, Dr. Stevenson substantially changed the conclusions of his expert report. Specifically, Dr. Stevenson's errata reversed the comparative results of his "no litter" and "no litter plus buffer" scenarios, and also increased by fivefold the relative increase in the predicted phosphorus concentrations for his "continued growth" scenario.

Because Dr. Stevenson did not provide any basis for abandoning his original method, or any statistical analyses to support his claim, the accuracy and reliability of his methods are not documented or established.

OPINION ON EXPERT REPORT BY DRS. G. DENNIS COOKE AND EUGENE WELCH

1. The results for future concentrations of total phosphorus (TP) and dissolved oxygen in Lake Tenkiller that Dr. Wells provided to Drs. Cooke and Welch are flawed and unreliable, consequently, to the extent that they relied upon Dr. Wells' results, all of their opinions about future lake conditions are also flawed and unreliable.

In their joint expert report, Drs. G. D. Cooke and E.B. Welch use concentrations of TP and dissolved oxygen in Lake Tenkiller as indicators of water quality. Throughout their expert report, Drs. Cooke and Welch put forth opinions on future conditions in Lake Tenkiller that rely upon predictions of future TP and dissolved oxygen concentrations in the lake from Dr. Wells' model. Because the predictions provided by Dr. Wells are flawed and unreliable, all of the opinions put forth by Drs. Cooke and Welch that relied upon these predictions are also flawed and unreliable.

REFERENCES

Chaubey, I., C.T. Haan, S. Grunwald and J.M. Salisbury. 1999. Uncertainty in the model parameters due to spatial variability of rainfall. Journal of Hydrology. 220:48-61.

Engel, B., D. Storm, M. White, J. Arnold and M. Arabi. 2007. A hydrologic/water quality model application protocol. Journal of the American Water Resources Association. 43(5):1223-1236.

Gerwig, B.K., K.C. Stone, R.G. Williams, D.W. Watts and J.M. Novak. 2001. Using GLEAMS and REMM to estimate nutrient movement from a spray field and through a riparian forest. Transactions of the American Society of Agricultural Engineers. 44(3):505-512.

Haraughty, S. 1999. Comprehensive Basin Management Plan for the Illinois River Basin in Oklahoma. Water Quality Division, Oklahoma Conservation Commission.

Hilborn, R. and M. Mangel. 1997. The Ecological Detective: Confronting Models with Data. Monographs in Population Biology. No. 28. Princeton University Press, Princeton, NJ.

Knisel, W.G. and F.M. Davis. 2000. GLEAMS: Groundwater Loading Effects of Agricultural Management Systems. Version 3.0. Publication No. SEWRL-WGK/FMD-050199. Revised August 15, 2000.

Mills, W.B., D.B. Porcella, M.J. Ungs, S.A. Gherini, K.V. Summers, L. Mok, G.L. Rupp, G.L. Bowie and D.A. Haith. 1985. Water Quality Assessment: A Screening Procedure for Toxic and Conventional Pollutants in Surface and Ground Water (Revised 1985), Part I. U.S. Environmental Protection Agency, Athens, Georgia. EPA/600/6-85/002a.

Pickup, B.E., W.J. Andrews, B.E. Haggard and W.R. Green. 2003. Phosphorus Concentrations, Loads, and Yields in the Illinois River Basin, Arkansas and Oklahoma, 1997-2001. U.S. Geological Survey Water Resources Investigations Report 03-4168.

SERA-17. 2005. Predicting Phosphorus Losses. Position paper by Phosphorus Management and Policy Workgroup.

Shoemaker, L., T.Dai and J. Koenig. 2005. TMDL Model Evaluation and Research Needs. Report prepared for National Risk Management Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio. EPA/600/R-05/149.

Terrio, P.J. 2006. Concentration, Fluxes, and Yields of Nitrogen, Phosphorus, and Suspended Sediment in the Illinois River Basin, 1996-2000. U.S. Geological Survey Scientific Investigations Report 2006-5078.

Thomas, M.A., B.A. Engel, M. Arabi, T. Zhai, R. Farnsworth and J.R. Frankenberger. 2007. Evaluation of nutrient management plans using an integrated modeling approach. Applied Engineering in Agriculture. 23(6):747-755.

Tortorelli, R.L. and B.E. Pickup. 2006. Phosphorus Concentrations, Loads, and Yields in the Illinois River Basin, Arkansas and Oklahoma, 2000-2004. U.S. Geological Survey Scientific Investigations Report 2006-5175.

U.S. Environmental Protection Agency. 2008. Draft Guidance on the Development, Evaluation, and Application of Environmental Models. Council for Regulatory Environmental Modeling, U.S. Environmental Protection Agency, Washington, DC.

U.S. Environmental Protection Agency. 2002. Guidance for Quality Assurance Project Plans for Modeling. EPA QA/G-5 M. EPA/240/R-02/007. Office of Environmental Information, Washington, DC.

Vanoni, V.A. (ed.). 1975. Sedimentation Engineering: American Society of Civil Engineers, Manuals and Reports on Engineering Practice, No. 54.

Watershed Conservation Resource Center. 2005. Geospatial Inventory and Assessment of Sediment from Unpaved Roads in the North Big Creek, Chandler Creek, Lick Creek Branch Watersheds, Sub-watersheds of the Strawberry River Watershed, Arkansas. Final report submitted to The Nature Conservancy.

Wells, S.A. 2005. Surface Water Hydrodynamic and Water Quality Models: Use and Misuse. Paper presented at 23rd Annual Water Law Conference, American Bar Association, Section of Environment, Energy and Resources, San Diego, California, February 24-25, 2005.

TABLES

Table 1. **Sample Table A-19 in GLEAMS 3.0 Manual (Knisel and Davis 2000) with Nutrient Parameter File for Broiler Litter Applied on Bermuda Grass 4 Times per Year with Multiple Cuttings of Grass**

Table A-19. Sample GLEAMS 3.0 nutrient parameter file for broiler litter applied on bermuda grass 4 times per year with multiple cuttings of grass

```
Card
No.
----
 1       GLEAMS version 3.0. Watkinsville Broiler litter plots
 2       1972-73; treatment B2--5 T BL/ac May, June, July, August
 3       Bermuda grass with multiple cuttings per year; no animal waste prior to 1072
 4          1972     1973        1        2        0
 5         750.0      0.8
 6         0.055    0.055    0.043    0.043    0.021
 7          10.0     10.0      7.0      7.0      3.0
 8         150.0    150.0    230.0    230.0    115.0
 9           0.0
10
11           3.0      3.0      2.0      2.0      1.0
12           0.0
13          1001
14             1        0     1188
15            10        0   2500.0
16          1159        1        0       15
18          8.81      0.0     2.81     2.08     0.72     1.50     1.47     78.0        1
13          1180
14             2        0     1220
15            10        0   3000.0
16          1192        1        0       15
18          8.18      0.0     3.08     2.26     0.81     1.35     1.32     78.0        1
16          1220        1        0       15
18          6.27      0.0     3.41     2.48   1.1209     1.51     1.48     78.0        1
13          1221
14             0        0     1240
15            10        0   2500.0
13          1250
14             0        0     1284
15            10        0   2000.0
13          1285
14             0        0     2100
15            10        0   1000.0
13          2101
14             0        0     2136
15            10        0   2000.0
13          2137
14             1        0     2164
15            10        0   2500.0
16          2138        1        0       15
18          8.30      0.0     3.35     2.44     0.90     1.51     1.48     78.0        1
13          2165
14             1        0     2192
15            10        0   3500.0
16          2171        1        0       15
18          8.21      0.0     1.85     1.44     0.40     1.15     1.13     78.0        1
13          2193
14             1        0     2218
15            10        0   4000.0
16          2100        1        0       15
18          8.36      0.0     2.11     1.61     0.49     0.96     0.94     78.0        1
13          2219
14             1        0     2247
15            10        0   3500.0
16          2226        1        0       15


18          8.03      0.0     2.67     1.08     0.68     1.24     1.22     78.0        1
13          2248
14             0        0     2277
15            10        0   2500.0
13          2278
14             0        0     3105
15            10        0   1000.0
13             0
```

Table 2. Sample Table A-20 in GLEAMS 3.0 Manual (Knisel and Davis 2000) with Plant Nutrient Parameter File, Default Initialization, 2-Year Rotation, Inorganic Fertilizer and Animal Manure

Table A-20. Sample GLEAMS 3.0 plant nutrient parameter file, default initialization, 2-yr rotation, inorganic fertilizer and animal waste

```
Card
 No
....
  1     GLEAMS 3.0 plant nutrient parameter file
  2     2 year corn-soybean rotation; default N and P pool initialization
  3     2 animal waste apps on corn. starter fertilizer on soybeans
  4        1980    1980       0       2       1
  5
  6
  7
  8
  9
 10
 11
 12
 13        1001
 14           2       3    1244
 15          20
 16        1091       1       1       2
 18         5.0    10.0     4.4    3.32    1.06     .82     .70    86.0       1
 16        1140       1       0       2
 18         3.0     0.0     4.4    3.32    1.06     .82     .70    86.0       1
 19        1091      10    10.0
 19        1091      22     4.0
 19        1255      10    15.0
 13        2001
 14           1       3    2300
 15          58
 16        2100       0       1
 17         0.0    33.0    45.0    10.0
 19        2100       4    15.0
 19        2100      22     4.0
 19        2305      10    15.0
 13           0
```

Table 3. Sample Table A-21 in GLEAMS 3.0 Manual (Knisel and Davis 2000) with Plant Nutrient Parameter File for Forest, Default Initialization, 7-Year Simulation, No Harvest, No Fertilizer, No Tillage

Table A-21. Sample GLEAMS 3.0 plant nutrient parameter file for forest, default initialization, 7-yr simulation, no harvest, no fertilizer, no tillage.

```
Card
 No.
----
  1       GLEAMS 3.0 plant nutrient parameter file. pine forest, 7-yr simulation
  2       Default N and P pool initialization
  3       Forest with 5 years in forest prior to simulation; no harvest; no fertilizer
  4           1980    1986       0       1       1
  5
  6
  7
  8
  9
 10
 11
 12
 13           1001
 14              0       0    2366
 15             60
 13              0
```